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Investigation to Uncover the Electrophysiological Correlates of the Mediating Cognitive Factors, Responsible for the Immediate Emotional Enhancement of Memory

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How to cite:

WATTS, SARAH (2015) *Investigation to Uncover the Electrophysiological Correlates of the Mediating Cognitive Factors, Responsible for the Immediate Emotional Enhancement of Memory*, Durham theses, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/11069/

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Abstract

Emotional memories are powerful memories that have markedly different phenomenological characteristics, compared to neutral memories. Emotional memories are adaptive and serve to aid survival of organisms. Evidence suggests that emotional events tend to be remembered with a greater depth of sensory and perceptual detail. The phenomenon around such memories has therefore been coined, emotion-enhanced memory (EEM). Much of the research into EEM has focused on the long-term consolidating affects that emotions can have upon memory; with the modulation hypothesis being the predominant theory in the literature. However, it has been noted in the literature that emotional stimuli can also enhance short-term memories, immediately after test. It is suggested that the immediate EEM is driven by changes in the cognitive attributes of emotional stimuli, which facilitates encoding processes; this is known as the cognitive-mediating account of immediate EEM. This research aims to investigate three of the key cognitive mediating factors, implicated in the behavioural literature; distinctiveness, relatedness and attention. Using electrophysiological recordings and event-related potentials, this work aims to further the behavioural research and develop functional accounts of how these cognitive factors can influence the immediate EEM. The results suggest that distinctiveness plays a significant role in the immediate EEM and a functional two-step model is proposed to outline the mechanisms through which it exerts it influence. This works also suggests overt attentional resources play a key role, as part of distinctiveness processing. The results did however find, contrary to the behavioural literature, relatedness is unable to fully account for the immediate EEM. These results are interpreted as supporting a complimentary model of EEM, which involves both the cognitive-mediating account for the immediate EEM and the modulation hypothesis for long-term EEM. These findings are discussed in terms of the real-world implications that emotional memory research can have.

Investigation to Uncover the Electrophysiological Correlates of the Mediating Cognitive Factors, Responsible for the Immediate Emotional Enhancement of Memory

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Submitted for the degree of

Doctor of Philosophy

The University of Durham

Department of Psychology

2014

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Declarations

This thesis is based on research carried out at the Department of Psychology, at the University of Durham. No part of this thesis has been previously submitted for a degree at this or any other institution. The work presented here is my own.

Publication

The work in Chapter 2 of the thesis has appeared in publication as follows:

The neural fate of neutral information in the emotion-enhanced memory (published in, Psychophysiology) 2014; Watts, S., Buratto, L. G., Brotherhood, E. V., Barnacle, G. E., & Schaefer, A.

As lead author I was responsible for; the collection of the data, the data analysis, reviewing the literature and writing up the results. The other authors contributed to the aiding some of the data collection and providing an input in the writing for publication. As such, I am confident my contribution to this Chapter is sufficient to allow me to include the work in my thesis.

Statement of Copyright

"The copyright of this thesis rests with the author. No quotation from it should be published without the author's prior written consent and information derived from it should be acknowledged."

Acknowledgments

Firstly I would like to thank my supervisor Alexandre Schaefer, for the unwavering help and support he has given me over the past 4 years. Through Alex's belief in me, I was offered the opportunity to study for a PhD at Durham University; without his input, this journey would never have been possible. I would like to thank you for your continual guidance and for being a sounding board for ideas, which helped form the basis of my research. You have always offered your time to critically evaluate my work - even after you moved away from Durham.

Secondly, I would like to thank those with whom I worked closely to during my time at Durham University. Special thanks to Luciano Buratto, Emily Brotherhood and Nazool-e Tabassum who were always there to lend a hand when times got tough and helped keep the busy EEG lab running smoothly.

I would like to give a big thank you to the many friends I have made whilst studying at Durham, particularly Helen Knight and Stephen Dunne. You have always had an encouraging influence on my work.

Finally I would like thank my loving family - my mother, who has supported me from the very start and whose belief has been unfaltering; my brothers and sister, Simon, David and Jenny who have put up with my many stressful moments and renewed my focus when the end seemed far away; lastly my partner Matt, who has been a tower of strength and my best friend throughout.

Chapter 1: Introduction

1.1 Chapter Overview

This chapter introduces the concept of emotion and how it interacts with memory. This work covers a brief history of the research into emotion and memory and explains how, with the emerging field of cognitive neuroscience, emotion memory interactions have become a prominent feature of cognitive research. This work describes the advances in neuroscience methodology that have contributed to this line of investigation and highlights how the subsequent memory effect has been very influential to uncovering current theories and models of the emotional enhancement of memory (EEM). This chapter sums up the current thinking on EEM and makes a key distinction between the prolonged and immediate effects emotion can have upon memory. It concludes, by stating the work in this thesis will focus on uncovering the neural correlates of emotional memory and the functional meaning this has for the cognitive mediating factors responsible for the immediate EEM.

1.2 What is Emotion?

To systematically and scientifically study a concept, it usually requires a consensual and central definition (Scherer, 2005). However, William James asked, 'What is an Emotion?' way back in 1884 and today that same question is still being asked. Agreeing on a concrete definition of emotion is a difficult task and one that has been debated in the literature for many years (Scherer, 2005). Difficulties of this task firstly lie in the concept of emotion itself; emotion can encompass many different things, ranging from physical bodily changes in facial expression, to conscious feeling of emotions or moods (Scherer, 2005). To further impact this problem emotions can be highly individual experiences with these experiences differing between different cultures and languages (Scherer, 2005). Hence, coming up with an inclusive definition of such a wide ranging concept has proven very challenging.

To combat this challenge and allow systematic investigations of emotion, brain-based cognitive neuroscientists have taken a pragmatic approach and isolated emotion from other states of affect, to agree on a componential theory of emotion (Ward, 2006; Scherer, 2005; Damasio, 2000). As such emotions have been defined as action schemas or processes that prepare the organism for certain behaviours, particularly behaviours associated with survival value such as mating or threats (Ward, 2006). Emotions occur as a result of an instigating event and can be characterised by a physiological disturbance to the organism, whereby there are changes in gestures, facial expressions, behaviours and beliefs (Power & Dalgleish, 1997). An emotion consists of specific and consistent collections of physiological responses and emotions together are part of a broader bio-regulatory device, which is needed to maintain life (Damasio, 2000).

With this definition it becomes essential to distinguish between what emotions are and what they are not. As such, it is important to differentiate between emotions and feelings. Damasio (2000) states that emotion and feelings are part of the same continuous process; although today it is common place to refer to emotion and feeling as one in the same thing they are in fact crucially, two distinct phenomena. Emotions are relatively public and should be used to refer to the collection of physiological responses triggered by brain systems, when the organism encounters certain situations or objects (Damasio, 2000). In contrast, the term feeling refers to the relatively private mental experience of an emotion (Damasio, 2000). As such, it is possible to observe an emotion in another person and observe the aspects of emotion that have caused a particular feeling; however you cannot plainly observe a feeling in another person (Damasio, 2000). Recognising your feelings and knowing what you feel is a subjective and conscious aspect of emotion, which occurs along the continuum of emotional experience (Ward, 2006). Conscious feelings however are not required to produce an emotional response, as most of the emotional response is attributed to unconscious cognitive processing mechanisms (Ward, 2006; LeDoux, 2000; Power & Dalgleish, 1997). Similarly, it is important to distinguish emotion from mood. Whereas emotion refers to processes or states that prepare the organism for certain behaviours (e.g. Fear is an emotion), a mood refers to a situation in which, a certain emotion or a collection of emotions frequently occur (e.g. anxiety is a mood; Ward, 2006).

1.3 When did research into emotions begin?

Research into emotions can be traced back to the Greek philosophers Plato and Aristotle, who both devised early theories on emotion (Power & Dalgleish, 1997). René Descartes (1649) later published a book titled ‘Les passions de l’âme’; this book debated and theorised about the ‘passions’ or emotions as we now more commonly refer to them. Into the 19th century research into emotions had developed with Charles Darwin publishing work on the expression of emotions and behaviours from a genetic perspective; it was proposed that emotions, rather like other aspects of behaviour, evolved over time (Darwin, 1998). Other prominent scientists such as William James and Sigmund Freud also wrote extensively about emotions and developed theories (Damasio, 2000). Despite such prominent figures developing ideas about emotion, for many years emotion was deemed as too subjective an area to be empirically studied, by the mainstream scientific community (Damasio, 2000).

In an attempt to unify emotion research and give a solid foundation upon which emotions could be empirically investigated some researchers aimed to identify a group of basic emotions. The notion of a set of basic emotions refers to a group of discrete emotions that are universal and recognised across cultures. Darwin was one of the first scientists to suggest that a set of basic emotions existed when he published his book, 'The Expression of the Emotions in Man and Animals' in the latter half of the 19th century. The book proposed that human emotions had evolved over time; as such, this would mean there are a finite list of emotions that are discrete in their adaptive nature and physiological expression (Darwin, 1998). More recently, research into basic emotions has been predominately lead by Ekman and colleagues (Ekman & Friesen, 1971; Ekman, 1992a; Ekman, 1992b; Ekman, 1993; Sauter, Eisner, Ekman & Scott, 2010). Ekman, rather like Darwin, views emotions as having an adaptive value, with each emotion having a unique physiology (Ekman, 1992a). An early study by Ekman and Friesen (1971) investigated if the facial expressions associated with certain emotions can be recognised across three diverse cultures. The results from this work and others demonstrated that facial expressions for six basic emotions (happiness, sadness, anger, disgust, fear and surprise) could be isolated and are the same across the diverse cultures (Ekman et al., 1971; Ekman, 1992a; Ekman, 1993). This work has recently gone beyond facial expressions of emotion and has been extended to examine the cross-cultural recognition of nonverbal emotional vocalisations (Sauter et al., 2010). The results have suggested that some emotions (primarily negative emotions) have vocalisations that can be recognised across cultures (Sauter et al., 2010). This work demonstrates that some emotions are universally recognisable in both facial expressions and vocalisations. As Gazzaniga, Ivry and Mangun (2008) point out, there is still considerable debate over basic emotions and of one single list can ever comprehensively establish the full extent of human emotions. However, the notion of basic emotions has been a useful basis upon which empirical research into emotions has been able to develop.

Emotion research was however not restricted to identifying basic emotions and other groups of researchers focused their investigation into the subjective nature of emotion itself. Some early theories of emotion focused primarily on the subjective feeling of emotion and somatic markers. Both William James and Carl Lange independently devised theories of emotion; they proposed that physiological arousal as a result of a stimulus, causes a subsequent physical bodily change (e.g. raised heart rate) and it is the self-perception of that bodily change that produces the emotional experience (Cannon, 1987). Although the theorists focused on different aspects of emotion (Cannon, 1987), this radical notion that bodily changes as the result of a stimulus cause the emotional experience, rather than the other way round, the ideas were combined and later called the James-Lange theory of emotion (Ward, 2006). Although there is now strong evidence to suggest that the self-perception of bodily changes alone is not sufficient to produce an emotional experience (Schacter & Singer, 1962) this historical hypothesis has still had influence in modern day theories of emotion. Damasio (1996) developed a theory called the somatic marker hypothesis; this posited that during decision making, we use previously acquired cognitive and emotional information, both consciously and unconsciously, to guide our decisions. This emotional information can manifest as somatic markers, or physiological bodily changes, which can reinforce an association between a stimulus and an affective state; this can result in an emotional influence to decision making. These somatic markers are thought to be stored and processed in the ventromedial frontal cortex.

In contrast to the early subjective theory of emotion from James-Lange, subsequent theories of emotion developed an interest in cognition and how emotions and evaluated. Two prominent cognitive theories of emotion come from Zajonc (1980; 1984) and Lazarus (1982, 1984). Zajonc (1980; 1984) proposed that affect comes first in the process of evaluating emotion, whereby there is an affective evaluation of whether the stimulus is threatening or positive; this is followed by a subsequent more substantial cognitive evaluation. Whereas Lazarus argued for a more appraisal-based theory of emotion and suggested that there has to be a level of cognitive appraisal for an emotional experience to occur and that Zajonc's affective evaluation needed a cognitive element.

One final avenue of emotional research has combined the cognitive aspects of emotional research with neuroscience and bridged the gap between the two fields to develop a unique field of cognitive neuroscience. An early approach which developed from this emerging field of research, attempted to uncover the neuroanatomy of emotion; the papez circuit as it became known, identified primarily the limbic system, including the hippocampus and hypothalamus as key regions responsible for emotions (Ward, 2006). MacLean (1949) furthered this line of research and identified other areas such as, the amygdala and orbitofrontal cortex that should be added to the papez circuit to create an integrated 'emotional brain' (Ward, 2006). This early theory viewed emotion as unitary concept, which could be isolated to one neural circuit (Gazzaniga et al., 2008). As research into these limbic areas continued, it became clear that certain structures such as the hippocampus played a crucial role in other cognitive functions such as memory; this highlighted that the limbic system and 'emotional brain' were not solely responsible for emotion and the structures of the limbic system are involved in other cognitive processes (Ward, 2006).

Recently the field of cognitive neuroscience research has expanded, with modern brain scientists seeing emotion as a product of brain activity, thus a measurable concept worth systematic empirical investigation. This, coupled with the development of methodological advances in safe imaging studies has meant emotion research is now a prominent feature of cognitive neuroscience. Current theories of emotion still refer to the limbic system, however research now tend to focus on the neural circuits underlying specific emotional behaviours and the related brain regions beyond the limbic structures, involved (Gazzangia et al., 2008). Current theories of emotion have focused on the role of the amygdala in both emotion and cognition processes. The amygdala is a small almond shaped structure found in the medial temporal lobe, with extensive connections to other brain regions such as the hippocampal complex and the prefrontal cortex; it is due to these connections that the amygdala is perfectly placed to influence both emotional and cognitive functions (Phelps, 2006). The amygdala in humans has been strongly associated with detecting fear, with studies demonstrating that there is enhanced activity of the left amygdala, when processing fearful faces (Morris et al., 1998). Evidence from the literature has also shown how the amygdala is particularly important to detecting arousal aspects of negative emotions (Adolphs, Russell & Tranel, 1999). This is consistent with the notion that the amygdala has an adaptive function in detecting fear or threatening stimuli and that this process can occur very quickly and sometimes without conscious awareness (LeDoux, 2000; Ohman, 2005). Recently the literature has outlined a neural pathway of action, which proposes the key role of the amygdala in detecting fear is to coordinate the cortical networks that the amygdala is linked to; it is then these cortical structures that are responsible for evaluating the biological significance of the stimuli (Pessoa & Adolphs, 2010).

The field of cognitive neuroscience now dominates research into emotion and highlights how research into emotion is now intimately linked with processes of cognition; as such, the two disciplines are now studied as one (Phelps, 2006). Research into emotion now focuses on uncovering the neural networks responsible for emotion and particularly the cognitive aspects associated with emotion, such as emotional learning, how emotion influences attention and perception and emotional memory (Phelps, 2006).

1.4 Emotions and Memory

William James wrote in *The Principles of Psychology*, “An impression may be so exciting emotionally as almost to leave a scar upon the cerebral tissues” (James 1890, p. 670). Hence, the adaptive function of emotions has long been documented in the literature, with the notion that emotions allow organisms to safely interact with their environment (Ekman, 1992a; LeDoux, 1995, 2003; Darwin, 1998; Cahill & McGaugh 1998; Morris et al., 1998; Hamann, 2001; Phelps, 2006). When a stimulus elicits an emotion, from an evolutionary perspective, that emotion is signalling to the organism that the stimulus is likely to have both immediate and future relevance (Hamann, 2001). For example, when a threatening stimulus elicits a fearful emotion, this signals to the organism that there is the need for an immediate response; it would also enhance survival success if the location of the threatening stimuli, was committed to memory. Hence, a part of the adaptive function of emotion relies on the formation of memories.

The link between emotions and memory has been noted in the literature, with memories for emotional events known to have markedly different phenomenological characteristics (Schaefer, Pottage & Rickart, 2011). Evidence shows that emotional events tend to be remembered with a greater depth of sensory and perceptual detail, compared to neutral memories (Schaefer & Philippot, 2005). Research has shown that emotional memories tend to have enhanced detail for central aspects rather than peripheral details of the memory (Christianson & Loftus, 1990). Such increased detail has led to the notion the emotional memories can have a photographic trace and as such have been previously referred to as 'Flashbulb' memories (Brown & Kulik, 1977). The literature has outlined several theories surrounding the unique nature of emotional memories, which attempt to define the key features of emotional memories and the real-life implications that such memories can have.

1.4.1 Flashbulb memories

As mentioned, the term Flashbulb memory refers to a memory for a surprising and emotionally arousing event (Brown & Kulik, 1977). Flashbulb memories are associated with highly detailed and vivid recollections that Brown and Kulik (1977) argued, are permanently stored in memory. Furthermore, flashbulb memories are often associated with contextual details of where the person was when they heard the information and details of how they heard the information (Brown & Kulik, 1977). Brown and Kulik (1977) suggested that flashbulb memories are biologically significant as they are formed due to a surprising and emotionally arousing event; hence, they argue, this biological basis could account for a distinct memory process that accompanies flashbulb memories. As such, this indelible memory mechanism has been likened to permanently printing the details in memory (Eysenck & Keane, 2005). Many studies have investigated the notion of flashbulb memories, surrounding particular dramatic world events, such as the assassination of President John F. Kennedy (Brown & Kulik, 1977), the death of Princess Diana (Davidson & Glisky, 2002; Kvavilashvili, Mirani, Schlagman, Erskine & Kornbrot, 2010) and the terrorist attacks of September the 11th 2001 (Greenberg, 2004; Schmidt, 2004; Hirst et al., 2009). Much of this research however has stimulated debate as to the unique features of flashbulb memories.

Brown and Kulik (1977) proposed that flashbulb memories relied on a special neural mechanism, which resulted in the unique features such as, enhanced detail, increased vividness and ling-lasting nature. Conway et al., (1994) support the view that flashbulb memories are special, however they argue that flashbulb memories rely on similar neural processes as other autobiographical memories. They suggest that these neural processes are more integrated for flashbulb memories, which results in the unique features of these memories, such as enhanced detail. Similarly, Tinti, Schmidt, Testa and Levine (2014) suggest that flashbulb memories do rely on distinct processes, as they utilise rehearsal of perceptual details and personal circumstances, in a way that other event memories do not do, which results in an enhanced vividness and detail of flashbulb memories. Although this evidence does support the distinct nature of flashbulb memories, as proposed by Brown and Kulik (1977), these accounts do not suggest that this is due to unique neural processes. Davidson and Glisky (2002) however do speculate that the special nature of flashbulb memories could involve the amygdala, mediating and enhancing activity in the frontal lobe, which in turn could then lead to increased detail and vividness of flashbulb memories. A more recent view suggests that the speciality of flashbulb memories compared to other to other every-day memories is more likely to be due to the unique phenomenological properties, associated with flash bulb memories; for example, the increased rehearsal associated with flashbulb memories can lead to enhanced recollection, vividness and confidence of the memory (Talarico & Rubin, 2007).

Another area of controversy associated with flashbulb memories is the increased level of detail and accuracy that often accompanies the memory. Brown and Kulik (1977) initially suggested that flashbulb memories and their associated detail are very long-lasting. However, evidence from the literature suggests that flashbulb memories are the same as other memories, in that they lose information from memory and are not absolutely accurate over time (Christianson, 1989). Contrary to the indelible account of flashbulb memories that Brown and Kulik (1977) suggest, Greenberg (2004) and Schmidt (2004) provide evidence to show how flashbulb memories are subject to decay and distortion and the memory for details becomes impaired over time. A current view on flashbulb memories states that they have similar forgetting patterns as other event memories (Hirst et al., 2009). In addition, it is now well documented that detail for flashbulb memories decline in line with everyday memories, but the level of confidence and perceived accuracy of flashbulb memories remains high over time (Talarico & Rubin, 2003; 2007).Despite the controversy over the exact nature of flashbulb memories, there is strong evidence to suggest that emotion has the ability to change the subjective feelings associated with emotional memories (Phelps, 2006).

1.4.2 Easterbrook Hypothesis

Another theory often applied to emotional memories is the phenomenon associated with attention narrowing, known as the Easterbrook Hypothesis (1959). Easterbrook (1959) proposed a cue utilisation theory, whereby as arousal increases the attention of the organism will be narrowed to central arousing cues of the stimulus. This leads to centrally arousing cues in the scene being successfully attended too and encoded in memory, whereas the peripheral cues of a stimulus are not attended too and subsequently not encoded. Attention in general is needed for organisms, so they can avoid sensory overload and only process information that is deemed important (Eysenck & Keane, 2005). Emotions have an adaptive value as they can mobilise certain action tendencies (e.g. flight response to a fearful emotion; Fredrickson & Branigan, 2005). As such, action tendencies require a narrowing of attention to enable to organism to focus on the arousing and emotion inducting stimulus, whilst disregarding peripheral information. Hence, emotional processing relies intimately on attentional processes.

Many studies have investigated this phenomenon and demonstrated the Easterbrook hypothesis and attention narrowing notion, that arousal enhances memory for central details, but impairs memory for peripheral details (Christianson & Loftus, 1989; Burke, Heuuer & Reisberg, 1992; Kensinger, Garoff-Eaton & Schacter, 2006). The attention narrowing properties of arousal and the subsequent effects on memory are however, not without debate (Mather, 2007; Christianson, 1992). Evidence has shown that in contrast to the memory narrowing hypothesis, arousal can impair memory binding (Mather et al., 2006). It has been suggested that the amygdala plays an important role in forming emotionally memories, enhancing memory for overall gist, but not especially for details (Adolphs, Denburg & Tranel, 2001; Adolphs, Tranel & Buchanan, 2005). Furthermore, evidence has shown that if the paradigm uses thematically induced arousal, rather than classic visual emotional stimuli, then emotional arousal has the ability to enhance all aspects of emotional memory, with no memory narrowing for central details (Laney, Campbell, Heur & Reisberg, 2004).

The impact of emotional arousal on attention narrowing has been shown to also vary according to the valence of the emotional stimulus. Where negative emotions have widely been shown to results in arousal induced attention narrowing (Christianson et al., 1989; Burke et al., 1992; Kensinger et al. 2006), it has been proposed that positive emotions can broaden attentional resources (Fredrickson & Branigan, 2005; Rowe, Hirsh & Anderson, 2007). Fredrickson et al., (2005) have suggested a broaden-and-build theory of positive emotions. The adaptive significance of negative emotions, as mentioned, is to promote and support specific actions (e.g. flight response) that can narrow attention and thought-action tendencies (Fredrickson et al., 2005). However, positive emotions it is argued, do not engage the same type of specific action (Fredrickson et al., 2005) and in contrast positive emotions can broaden thoughts and actions (e.g. to play and explore). Such broadened actions in response to positive emotions have the adaptive value of allowing an organism to build up a variety of resources (Fredrickson et al., 2005). Despite the evidence in favour of a broaden-and-build theory of positive affect (Fredrickson & Branigan, 2005; Rowe, Hirsh & Anderson, 2007), recent evidence has shown that when the positive emotion is high in approach-motivation, similar to negative emotion, it narrows the breadth of attention, as the organism seeks to approach the desired object and disregards irrelevant information (Gable & Harmon-Jones, 2008).

Research into the effects of narrowing attention in emotional memory have been particularly prominent to eyewitness testimony research, particularly with the findings associated with the 'weapon focus' effect (Loftus, Loftus & Messo, 1987). Weapon focus is a phenomenon whereby the attention of an eyewitness to a crime is focused on the weapon involved, which leads to a reduction in memory for other details of the crime (Loftus et al., 1987; Steblay, 1992). This highlights the effect emotionally arousing events can have upon memory and the specific importance to eyewitness testimony is discussed in more detail below.

1.4.3 Eyewitness Testimony

The final area that memories for emotional events can have important consequences is in the field of eye witness testimony. Eyewitness testimonies refer to the accounts of events given by a witness to a crime; often these crimes can be highly emotional or traumatic events for the witness involved. Evidence from the literature suggests that arousing and traumatic emotional events tend to have a strong memory for the general gist of the event, however memories for peripheral details of the event are poor (Christianson & Loftus, 1987). Specific studies investigating violent crimes have found that this effect was particularly evident when a weapon was used; this lead to what is now known as the weapon focus effect (Loftus et al., 1987). As mentioned above, the weapon focus effect refers to the phenomenon whereby during a violent scene, attention is narrowed to the weapon in the scene and detail for peripheral information in the scene is neglected (Loftus et al., 1987). Evidence suggests that the weapon focus effect can been extended to cover a more broad interpretation and encompass any arousing component of a scene, rather than a specific weapon; any arousing stimulus has the ability to reduce the details for peripheral information from the scene (Kensinger, 2004). This evidence demonstrates how emotional memories for traumatic events can be lacking in overall detail and thus highlights how there is a potential for eye witness testimonies to be unreliable accounts of events.

Research into eyewitness testimonies has shown that information provided after the event can distort the memory and affect the eyewitness's account. This phenomenon has been called the misinformation effect and was demonstrated in a study by Loftus and Palmer (1974). Participants were asked to watch the scene of a car crash, in which there was no broken glass and asked a leading question of estimating how fast the car was travelling when it was 'smashed into' or 'hit into', during the video clip. After a week delay participants were asked if there was broken glass at the scene; participants in the 'smashed' group were more likely to incorrectly reports seeing broken glass at the scene than the participants in the 'hit' group. This study was very influential and demonstrated that a leading question presented at encoding, coupled with a misinformation question a week later was enough to change the recall of that memory. Although many of these studies have surrounded the emotional details of car crashes, there is evidence to show that memory for non-arousing aspects of the memory (e.g. the presence of a barn) can equally be distorted with misinformation (Loftus, 1975). Despite this, evidence from the literature suggests that arousal does have a significant impact on memory above that of neutral aspects, as arousing violent crimes can impair memory for details presented up to 2 minutes earlier, than the violent event (Loftus & Burns, 1982). Christianson (1992) conducted a review into the evidence of emotional stress and its impact on eyewitness memory. It was concluded that emotional stress interacts in a complex way with the type of event and the level of detail recalled from the event and that emotional events may have access to preferential processing resources. This demonstrates that arousing events can have a particularly strong impact on the formation of emotional memories and the fragility of eyewitness testimonies.

The Innocent Project in the United States of America works to overturn wrongful convictions; of the first 225 exonerations they completed, 77% of the wrongful convictions were based on mistaken eyewitness testimonies (as reported in, Shermer, Rose & Hoffman, 2011). Hence this research has had a significant impact to judicial proceedings, such as police interview techniques and eyewitness identification procedures (Eysenck & Keane, 2005).

Taken together these three areas of research shows the diverse range of investigations into emotional memory and how several early theories were developed to understand the exact nature of emotional memories and what makes these types of memories unique. This research highlights how important research into emotional memories has been for areas such as eye witness testimony and judicial systems worldwide. As mentioned above (1.3, When did research into emotions begin?

Chapter 1), the explosion in the field of cognitive neuroscience research has meant that investigations into emotion and memory have moved away from general cognitive accounts of the features of emotional memory. Research now focuses more on the underlying processes that are responsible for specific aspects of emotional memories and how they have different phenomenological properties compared to other memory processes.

1.5 Valence and Arousal

As mentioned above (1.4 Emotion and memory, Chapter 1) there has been a long history of investigations onto the effects of emotion and memory. It is well established that emotional events are more likely to be remembered than comparative neutral events (Brown & Kulik, 1977; Christianson, 1989; Bradley, Greenwald, Petry & Lang, 1992; Cahill & McGaugh, 1998; Schaefer & Philippot, 2005; Talmi, Luk, McGarry & Moscovitch, 2007; Schaefer et al., 2011; Watts, Buratto, Brotherhood, Barnacle, Schaefer, 2014). However, there is still considerable debate as to how the aspects of arousal and valence contribute to enhanced emotional memory.

Arousal refers to a continuum that varies from calm to excitement (Dolcos, LaBar & Cabeza, 2004b); hence a stimulus that is highly arousing rates high on the excitement side of the scale. It has long been demonstrated in the literature that highly arousing items are more likely to be remembered that non-arousing or neutral items (Hamann, Ely Grafton & Kilts, 1999; Dolcos & Cabeza, 2002; Kensinger & Corkin, 2003; Sharot & Phleps, 2004; Anderson, Yamaguichi, Grabski & Lacka, 2006). In line with the Easterbrook hypothesis (see 1.4.1 Easterbrook Hypothesis, Chapter 1), it is suggested that arousing items are more likely to be attended too (Dolan & Vuilleumier, 2003) and thus successfully encoded into memory (Kensinger, 2009). Specifically, recent accounts posit that arousal particularly enhances memory for intrinsic details of a scene, rather than contextual detail (Kensinger, 2009). McGaugh (2004) and Cahill and McGaugh (1998) have investigated the mechanisms by which arousal affects emotional memories and have proposed the consolidation hypothesis. McGaugh (2004) suggests that arousal can enhance noradrenergic activation, which interacts with the amygdala and its efferent projections to structures such as the hippocampus, to mediate the long-term consolidation of emotional memories.

Several studies support this view and have found the amygdala is instrumental to mediating the effects of arousal upon memory. At memory encoding, activity recorded from the amygdala was found to correlate with subsequent memory performance for emotional stimuli (Hamann et al., 1999; Canli, Zhoa, Desmond, Glover & Gabrieli, 1999; Cahill et al., 1996). In addition, studies have also found that arousal mediated emotion enhancement of memory is associated with amygdala-hippocampal interactions (Kensinger & Corkin, 2004). This further supports the consolidation hypothesis (McGaugh, 2004) by providing evidence to suggest arousal effects of emotional memory do rely on amygdala projections to other limbic structures. Alongside encoding processes, the amygdala has also been shown to mediate the retrieval of emotional memories (Hamann, 2001; Buchanan, 2007). Kensinger and Schacter (2007a) found activity recorded in the amygdala, parahippocampal areas and orbitofrontal cortex corresponded with successful retrieval of emotional items. This evidence suggests arousal plays a key role in encoding emotional memories; a process that likely involves regions of the amygdala, limbic structures and areas of the cortex in both encoding and retrieval of emotional memories.

To what extent that valence of emotional stimuli effects emotional memory is still debated (Kensinger & Schacter, 2007b). Some evidence shows that valence does not have an effect on subsequent memory and whether the stimuli are negative or positive, there is still an emotional enhancement of memory (Bradley et al., 1992) and amygdala activity recorded at encoding was shown to be the same for negative and positive stimuli (Kensinger & Schacter, 2006). However, the literature also presents conflicting evidence; in some cases positive items were more likely to be remembered than negative items (Mather & Carstensen, 2005) whereas other evidence suggests negative items are more likely to be remembered than positive items (D'Argembeau & Van der Linden, 2005).

It has been suggested that the adaptive value of emotions can differ between negative and neutral emotional stimuli (see 1.4.2 Easterbrook, Chapter 1). It is thought negative items narrow attentional resources to the arousing stimuli and disregard peripheral details (Easterbrook, 1959), whereas positive items have been shown to increase attentional focus (Fredrickson et al., 2005). On the basis of these differences it has been suggested that the conflicting evidence surrounding the effect of valence on emotional memory could be due to the differences in the quality of the memory that valence produces (Kensinger, 2009; Kensinger & Schacter, 2007b). Kensinger (2009) proposes, in line with the Easterbrook hypothesis, that negative valenced items enhance memory for intrinsic detail of an emotional event; whereas, positive emotion, in line with Fredrick et al., (2005), increases the memory for gist of the event. The literature offers support to this account, with an fMRI study demonstrating that negative emotionally valenced items at encoding are associated with activity across temporal-occipital regions; whereas, positively valenced items were associated with activity across frontal-parietal regions (Mickley & Kensinger, 2008). It is suggested that these different areas of activity as a function of valence reflect the different processes that are recruited during the

encoding or negative compared to positive items. The temporal-occipital areas activated for the negative items likely reflect enhanced sensory processes, which would facilitate a memory for intrinsic details; however, the frontal-occipital activity of positive items likely reflect conceptual processes and would facilitate memory for gist, rather than detail (Mickley et al., 2008).
Overall this evidence shows that both arousal and valence can play a significant role in influencing the formation of emotional memories. This highlights the need to consider both aspects of emotion to fully understand how emotion interacts with memory and how real-life emotional events are remembered.

1.6 Emotion enhanced memory (EEM)

Memories for emotional events are known to markedly different phenomenological characteristics, compared to neutral memories (Schaefer, Pottage & Rickart, 2011). Emotional memories are often recalled with increased vividness (Brown & Kulik, 1977), increased detail (Schaefer et al., 2005) and increased confidence (Talarico et al., 2003). As mentioned above, this phenomenon has long been recognised in the literature, with several theories outlining key features of emotional memories. Numerous studies have replicated the effects of emotional memories in laboratory studies. The effect has been demonstrated using pictorial stimuli, with an enhanced memory for emotional pictures compared to neutral pictures (Bradley et al., 1992; Talmi, Luk et al., 2007; Talmi & McGarry, 2012; Watts et al., 2014); it has also been shown using both words (Talmi & Moscovitch, 2004; Schmidt & Saari, 2007) and narratives (Laney et al., 2004). Recently this phenomenon, whereby emotional memories are remembered better than comparative neutral memories has been coined the emotion enhancement of memory (EEM; Talmi, Schimmack, Paterson & Moscovitch, 2007). The explosion of cognitive neuroscience and the developments in safe methodologies has meant that research into emotional memory is now focused on uncovering the neural networks involved in specific aspects of emotional memory.

One predominant theory of how emotion enhances memory is the modulation hypothesis (Cahill & McGaugh, 1998; McGaugh, 2000; 2004). The modulation hypothesis (or consolidation hypothesis) proposes that emotion enhances memory through an arousal-mediation pathway that centres on the amygdala. McGaugh (2004) suggests that adrenal stress hormones released as a consequence of arousing emotional stimuli (negative and positive) activate receptors in the basolateral amygdala. This activation of the amygdala then in turn influences memory consolidation processes, both in the amygdala and in its projections to other important memory-storage processing brain regions, such as the hippocampus and prefrontal brain regions. It is through these interacting neuromodulatory brain systems and pathways that McGaugh (2004) argues, makes emotionally arousing items become well remembered.

There is strong evidence from both animal and human studies to support this account (see McGaugh, 2004; LaBar & Cabeza, 2006 for review). For example, studies have found that activity recorded at the amygdala during encoding, correlates with the long-term recall of emotional stimuli (Cahill et al., 1996; Canli et al., 1999; Hamann et al., 1999). Evidence from a study on a patient with bilateral amygdala damage showed no emotion enhanced memory for arousing stimuli (Adolphs, Cahill, Schul & Babinsky, 1997). These investigations provide support for the consolidation account of emotional memory proposed by McGaugh (2004) and confirms the important role that the amygdala plays in forming long-term emotional memories. Furthermore, more recent evidence has also shown amygdala activation can influence memory processes in other brain regions, such as para-hippocampal areas (Kensinger et al., 2004). This again provides support for the modulation hypothesis and confirms that the amygdala's projections to other memory-consolidating brain regions are critical to forming emotional memories. The modulation and consolidation of emotionally arousing memories does not happen immediately; it is a process thought to take an extended period of time (Cahill et al., 1998; McGaugh, 2000). The exact time frame of the consolidation process however is rather vague, with some estimates ranging from 30 minutes up to six months (Hamann, 2001). It is clear however that the general consensus is that the longer the process of consolidation has to take place, the more permanent and resistant to loss the memories become (Hamann, 2001).

This phenomenon surrounding the formation of long-lasting durable emotional memories has been termed EEM. Irrespective of the time-scale the process of consolidation takes, the current literature proposes that long-term emotional memories are formed through a modulation and arousal-mediated process, critically involving interactions from the amygdala.

1.7 Immediate EEM

Emotionally arousing stimuli are memorable and the neurobiological account described above (see 1.6 Emotion enhanced memory, Chapter 1) offers a concrete explanation for how emotion can enhance memory over time. However, it is well documented in the literature that emotion can enhance memory immediately after an event (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi, Anderson, Riggs, Caplan & Moscovitch, 2008; Schaefer et al., 2011; Talmi & McGarry, 2012;

Pottage & Schaefer, 2012; Watts et al., 2014). Hence, the modulation hypothesis (McGaugh, 2004) can explain the prolonged effects of emotion upon memory, but the process of consolidation takes time, therefore it cannot account for these immediate effects of emotion upon memory. Talmi, Schimmack et al., (2007) suggest the immediate effects of EEM are caused by cognitive mediating factors. They propose that the change in cognitive attributes of emotional stimuli, results in the mnemonic advantage for emotional items over neutral items presented immediately after an event (see Figure 1.1).

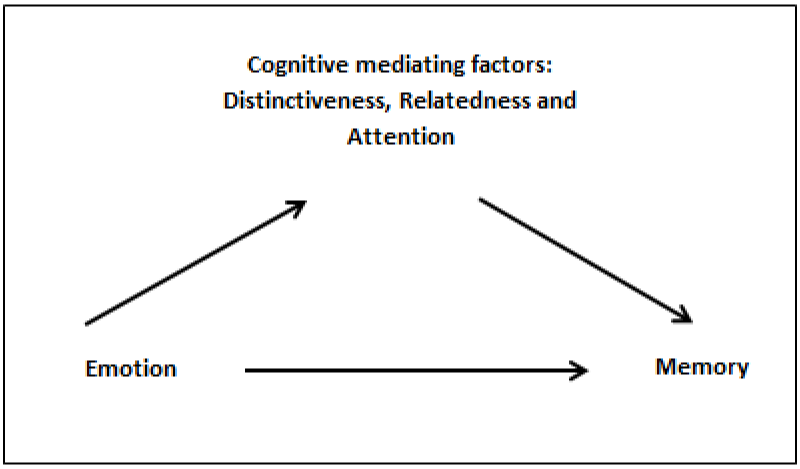

Figure 1.1: The cognitive mediation model proposed by Talmi, Schimmack et al., (2008). The straight arrow represents the modulation hypothesis and prolonged effects of EEM from McGaugh (2004). The double arrow represents the cognitive mediation factors of immediate EEM. *Figure adapted from Talmi, Schimmack et al., (2008).*

The behavioural literature outlines several possible cognitive factors that could mediate the emotional enhancement of memory. Firstly, it has been demonstrated that emotional stimuli are processed in a priority mode; whereby the amygdala has projections to sensory cortices, which provides a direct mechanism to enhance the encoding of emotional events (Vuilleumier, 2005). This priority processing can then improve the encoding of emotional stimuli (Schafer & Gray, 2007). It has been suggested that the priority processing of emotional stimuli could be because they have changed the cognitive attribute of attention and they thus capture more visual attention than neutral stimuli (Kensinger & Schacter, 2007b; Christianson, 1992). Another potential cognitive factor is that emotional items are deemed more distinct than neutral items (Dewhurst & Parry, 2000; Talmi, Luk et al., 2007; Talmi & McGarry, 2012; Watts et al., 2014), therefore are prioritised in processing.

Secondly, emotional stimuli are thought to trigger deeper level of meaning-based processing compared to neutral events (Schaefer et al., 2003). In particular, it has been shown that semantically encoding emotional stimuli can enhance recollection in memory (Talmi et al., 2004; Talmi, Luk et al., 2007; Talmi & McGarry, 2012). The notion that a deeper semantic based encoding process facilitates memory is not a new concept, as the paper on levels of processing by Craik & Lockhart (1972) demonstrates. However, this idea has been adapted and it is now proposed that the cognitive factor of semantic relatedness can mediate emotional memory and enhance subsequent memory performance (Talmi, Luk et al., 2007; Talmi & McGarry, 2012). In addition to the concept of meaning-based processing, the literature has shown that emotional events tend to be processed in a self-referential manner; incorporating emotional stimuli into our self-memory system (Conway & Pleydell-Pearce, 2000). This self-based processing can make encoding emotional stimuli more efficient and thus, improve the detail of the memory and make it more vivid compared to neutral stimuli (Schafer & Philippot, 2005). Hence, the enhanced self-referential processing of emotional stimuli could be an additional cognitive mediating factor that facilitates EEM.

Lastly, it has been shown that emotional events are often processed using higher executive functions. For example, emotional-regulation (the process of influencing when one experiences, and expresses emotions; Gross, 1998) has been shown to be an effortful process, which engages in central processes of executive control (Schmeichel, 2007). The controlled processes of emotional regulation have also been shown to interact powerfully with emotional memory (Richards & Gross, 2000; Gross, 2002). Hence, the cognitively controlled factor of emotional regulation could be a potential mediator in EEM. Furthermore, the literature presents evidence to support the view that executive processes may influence emotional memory. For example, Schaefer et al., (2006) found activity recorded at the amygdala corresponded with better performance on a working memory task. This provides important evidence to suggest that the amygdala is involved in executive processes and higher cognitive functions (Schaefer & Gray, 2007). The amygdala is also known to have a critical involvement in the formation of emotional memories (McGaugh, 2004); hence, it is possible the amygdala coordinates these processes of executive function and emotional processing. This evidence suggests that processes involving executive control could also act as cognitive mediating factors in EEM.

It is clear the behavioural literature provides a wealth of evidence to suggest that cognitive factors could play a mediating role in EEM. Recently Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) have conducted several investigations into the cognitive meditating factors they deem responsible for EEM and have outlined key factors which play role in immediate EEM: *distinctiveness, attention and relatedness.*

1.7.1 Distinctiveness

The literature proposes that emotional items are more distinct than neutral items, which facilitates encoding and improves the subsequent memory for emotional items (Talmi, Luk et al., 2007). Evidence has shown that improving the organisation and distinctiveness of items can enhance memory irrespective of emotionality (Hunt & McDaniel, 1993). Therefore it is reasonable to suggest that with the added factor of emotion, distinctiveness could play a part as a cognitive mediating factor in immediate EEM. Warranting further investigation, the research into the concept of distinctiveness and what makes an emotional visual image 'distinctive' can be traced back to the work of Detterman & Ellis (1972). They tested subsequent memory for a list of images made of nude people and line drawings of common objects and found that memory performance was better for nude pictures compared to line drawings. This they argued was down to the distinctiveness of the nude pictures, creating an induced amnesia; as the image of the nude was maintained in memory, they suggested this prevented encoding of the images that followed. This idea was later tested by Schmidt (2002), who suggested that maintaining the nude image in memory, should lead to a better memory for the details of the nude distinctive image. However, upon testing, Schmidt (2002) found that memory for details was equivalent between images of nudes and control images (clothed person). This evidence suggests that the distinctiveness of an item affects memory above and beyond creating an induced amnesia for the images that follow.

In investigating the properties of what makes an item distinctive, Schmidt (1991) developed a distinction within the concept of distinctiveness itself; proposing items can have relative (primary) distinctiveness and absolute (secondary) distinctiveness properties. Both these types of distinctiveness interact and rely on the active conceptual framework, which is a set of neutral items usually stored in long-term memory of everyday objects, such as people, buildings and cars. Items that are absolutely distinct, do not share any common features with items in the active conceptual framework, therefore they stand out and are deemed absolutely distinct. Relative distinctiveness on the other hand does have some limited overlap with features of the active conceptual framework. It is this limited overlap, which notifies a person that a particular item is similar to the background items but has some key differences; hence these differences make the items distinctive against the other items (see Figure 1.2). For example, Talmi, Luk et al., (2007) points out that an image of black letter presented in a stream of stimuli may stand out and be classified as absolutely distinct. However, if this black letter was presented in a stream of blue letter stimuli, it would be relatively distinct as it has some overlap with the other items, but the key differences are what make this black letter stand out against a background of blue letters and become relatively distinct. Schmidt (1991) concluded that is it relative distinctiveness that enhances memory, not absolute distinctiveness.

This effect was confirmed when a study used mixed lists of negative and neutral words and found that memory was enhanced for the negative words; as they were relatively distinct against the background of neutral words (Dewhurst & Parry, 2000). Similarly a study using emotional taboo words and non-taboo emotional words found memory performance for the taboo emotional words was better than non-taboo emotional words (Schmidt & Saari, 2007). This again supports the notion that it is the relative distinctiveness properties, which facilitate encoding and enhance subsequent memory performance.

More recently, this area has been investigated more thoroughly by Talmi and colleagues. Talmi, Luk et al., (2007) suggested that is it possible to experimentally manipulate the distinctiveness properties of stimuli, by changing a participants active conceptual framework and utilising a mixed versus pure list design. When emotional stimuli are presented in a pure list design, the working memory component of the active conceptual framework of that participant has been changed to contain mainly emotional items, as presented from the pure list. Hence, the items are only absolutely distinct; they must stand out against the background of emotional images in their own right to be distinctive. Whereas in a mixed list design that presents intermixed emotional and neutral stimuli, the working memory active conceptual framework will be manipulated and the negative items will stand out against the background of the neutral images, hence be relatively distinct (as explained above). It is important to note, that items presented in a mixed list condition also have absolute distinctiveness properties, in that they still have the ability to standout in their own right as absolutely distinct items, against the background of all the other items. Using this manipulation, studies have shown that the emotional enhancement of memory for emotional items is greatest in a mixed list condition (Talmi, Luk et al., 2007; Talmi & McGarry, 2012; Watts et al., 2014). Thus, confirming the notion it is that relative distinctiveness properties of stimuli that enhances memory and that the cognitive factor of distinctiveness is an important mediating influence in EEM and worth further investigations.

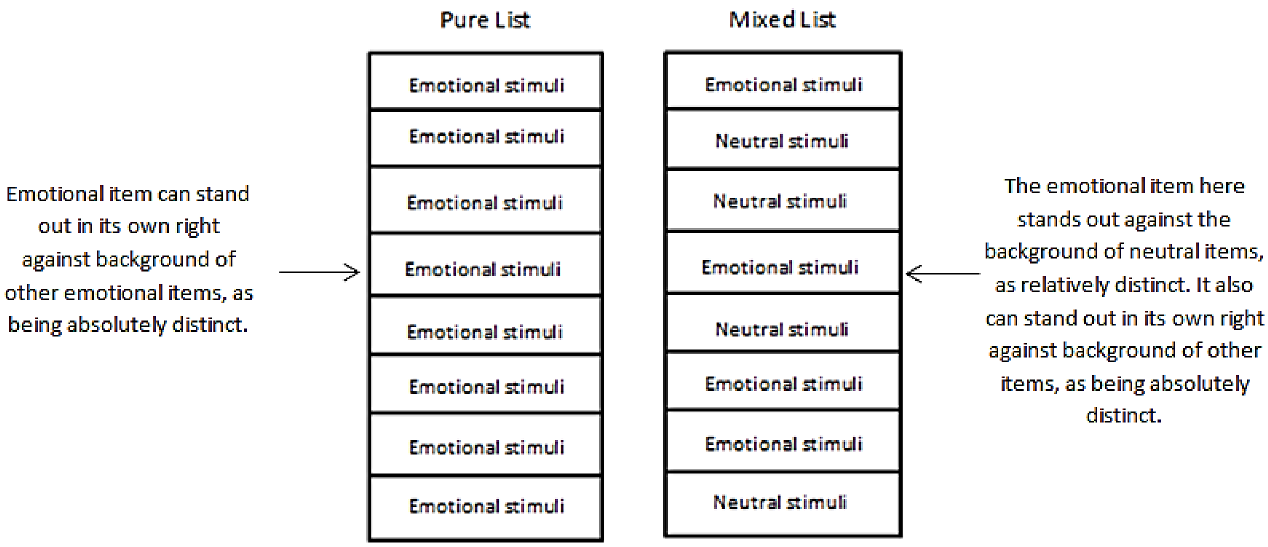

Figure 1.2: A visual illustration to differentiate absolute and relative distinctiveness, in a mixed versus pure list paradigm.

1.7.2 Relatedness

The factor of relatedness refers to semantic relatedness as outlined by Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry 2012). As mentioned above, investigating the role that encoding stimuli semantically has upon memory can be traced back to the studies of Craik & Lockhart (1972) and their hypothesis on levels of processing. They proposed that encoding stimuli semantically can aid encoding and facilitate memory. Furthermore Hunt and McDaniel (1993) have shown how adding the factor of organisation can benefit memory; as such, utilising the semantic relatedness of stimuli can create links between the items to aid the organisational process, facilitate encoding and enhance memory. Talmi, Luk et al., (2007) suggest that the inherent level of semantic relatedness found in emotional stimuli, make it easier to form thematic links between stimuli during encoding, which facilitates subsequent memory. To investigate this notion Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) have devised a negative picture set and a neutral picture set that are controlled for semantic relatedness, so that both picture sets are rated equally for semantic relatedness. Using these stimuli sets they have demonstrated that the mnemonic memory advantage for negative stimuli is removed and that subsequent memory performance for negative and neutral images, when they are controlled for semantic relatedness, is equal (Talmi, Luk et al., 2007; Talmi & McGarry, 2012). This influential finding strongly suggests that the semantic relatedness inherently associated with emotional stimuli could act as a cognitive mediating factor and facilitate EEM.

1.7.3 Attention

William James wrote in 1890, “Selection is the very keel on which our mental ship is built. And in this case of memory its utility is obvious. If we remembered everything, we should on most occasions be as ill off as if we remembered nothing.” (James, 1890 p.680). Hence, attention is critical to ovoid sensory overload (Eysenck & Keane, 2005). As demonstrated above with the Easterbrook hypothesis (1959; see 1.4.2 Easterbrook hypothesis, Chapter 1), attention plays a crucial part in emotion and memory. Items that are arousing are more likely to be attended too (Dolan et al., 2003) and encoded into memory (Kensinger, 2009). The Easterbrook hypothesis (1959) outlines how arousing emotional stimuli have the ability to narrow attentional focus and reduce memory for peripheral details of an emotional scene (Christianson & Loftus, 1989; Burke et al., 1992; Kensinger et al., 2006). On the other hand the literature provides evidence to suggest that positive emotional stimuli can broaden attentional focus, to promote positive adaptive functions such as exploring and play (Fredrickson et al., 2005). A current view states that any emotion that is high in approach-motivation, will reduce the attentional focus as the organism seeks out the desired object and disregards peripheral details (Gable et al., 2008). From the evidence it is clear that attention can influence the quality of emotional memories (Kensinger, 2009) and demonstrates that attention plays a crucial role in determining where processing resources should be allocated and what is then encoded into subsequent memory.

More specifically, the role of attention in EEM has been studied using classic divided versus full attention paradigms; whereby attention is allocated to a primary task (e.g. encoding an image), whilst simultaneously completing a secondary task (e.g. auditory tone discrimination), which depletes attentional resources. These paradigms are thought to deplete selective attentional resources, but leave pre-attentional resources unaffected (Kensinger & Corkin, 2004; Pottage & Schaefer, 2012). The findings from these studies however are mixed, with some literature suggesting that attention for positive emotional stimuli can fully account for enhancing emotional memories, whereas attention did not account for emotional memories with emotionally negative stimuli (Talmi, Schimmack et al., 2007). On the other hand, another study has demonstrated that visual attention can fully account for emotional memories involving negative emotional stimuli (Pottage et al., 2012). This contrasting evidence suggests that similar to the literature regarding the influence that attention can have upon the quality of emotional memories, the literature is divided as to the exact role that attention play in the immediate EEM. Despite the lack of clear conclusions presented in the literature, it is evident that attention does play a key role in emotional memories and can be an influential cognitive mediating factor to immediate EEM.

1.8 Methodology of EEM

1.8.1 Recall versus Recognition

The most common paradigms employed to test immediate EEM usually involve testing subsequent memory using either free recall or recognition studies. Free recall studies involve participants encoding a set of stimuli; then after a short delay they are requested to write down a brief but detailed description of the stimuli they can recall. This procedure has been widely used in EEM research (Bradley et al., 1992; Dolcos & Cabeza, 2002; Talmi & Moscovitch, 2004; Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012; Pottage & Schaefer, 2012; Watts et al., 2014) and is thought to be more akin to real-life recall, hence more ecologically valid (Talmi, Schimmack et al., 2007).

Recognition however involves participants encoding stimuli then, usually after a period of delay, they are presented with the original stimuli, intermixed with new stimuli. The participant must decide which stimuli they recognise as ‘old’ and having seen before at the original encoding; and what stimuli they recognise as ‘new’ having not seen it before at original encoding. Although recognition may not be as akin to real-life recall of emotional memories, these studies do have higher recall rates and thus more ‘hit’ trials, which are an important experimental and practical consideration when conducting ERP investigations; hence they have been used widely in emotional research (Ochsner, 2000; Sharot & Phelps, 2004; Sharot, Delgado, Phelps, 2004; Dolcos, LaBar & Cabeza, 2005; Sharot & Yonelinas, 2008; Schaefer et al., 2011). In addition, recognition studies also allow for a more in depth investigation into the quality of the remembered items, by using a remember versus know task, alongside the recognition paradigm (see Yonelinas, 2002 for review). This task is implemented in the recognition phase of the study and participants must decide if the item they remember the item exactly or if it only feels familiar. If the remembered item is accompanied by feelings of vividly remembering specific details of when you first encountered this item, this is classed as a ‘remember’ response. Alternatively, if the participant has a feeling the items is familiar but they cannot recall specific details of when the items was encounter, this is classed as a ‘know’ response. Many studies have utilised this paradigm and found that the different processes of ‘remember’ versus ‘know’ rely on distinct neural networks within the medial temporal lobe and the prefrontal cortex. Specifically activity of the parahippocampal cortex is associated with a ‘remember’ response and recollection, whereas, the perirhinal cortex is associated with a 'know' response and a feeling of familiarity (Ranganath et al., 2004; Yonelinas, Otten, Shaw & Rugg, 2005; Eichenbaum, Yonelinas & Ranganath, 2007). This paradigm has been very successful at forming a distinction in the quality of items that are remembered and sheds more light on the complex processes involved in encoding emotional memories.

1.8.2 Cognitive neuroscience of EEM

As mentioned recent developments in safe neuroscience techniques have greatly influenced the research into emotion (see 1.3 When did research into emotions begin? Chapter 1). They have particularly helped with researching the cognitive aspects of emotion, such as memory. Various neuroscience methods have been employed to investigate emotion and memory interactions. For example, imaging techniques such as fMRI (functional magnetic resonance imaging) and PET (position emission topography) have been vital to uncovering the neuroanatomical networks responsible for aspects of emotion.

For example imaging studies have revealed specific neural networks are involved in emotional processing according to emotional valence and emotional arousal (Dolcos, LaBar & Cabeza, 2004b; Mickley & Kensinger, 2008). They have progressed early work into emotional processing with the limbic system and uncovered specific regions, such as the amygdala, as being strongly involved in forming emotional memories (Hamann et al., 1999; Canli et al., 1999; Adolphs et al., 1997 Cahill et al., 1996). These studies have further revealed that the amygdala has specific projections to other regions, such as the hippocampus, to facilitate the formation of emotional memories (Kensinger et al., 2004). Recent evidence has also suggested that the amygdala has specific projections to cortical regions, which implies the cortex is involved in emotional processing more than previously thought (Pessoa & Adolphs, 2010). These findings have contributed to specific theories about emotional processing and memories, such as the consolidation hypothesis (McGaugh, 2004).

Similarly studies using EEG (electroencephalogram) recordings have revealed specific temporal dynamics to emotional processing. EEG is the general recording of electrical activity along the scalp, whereas ERP recordings are the averaged EEGs recorded in response to a specific time-locked stimulus (Luck, 2005). The majority of emotion research that records electrical activity from the scalp now focus on conducting ERP studies, as they are able to isolate electrical brain activity to specific stimuli and events and can therefore reveal more precise information.

Research using ERP studies have revealed important electrophysiological correlates of encoding processes involved in emotional memories. For example, Dolcos & Cabeza (2002) found an emotion effect, whereby waveforms associated with encoding emotional stimuli are more positive going than waveforms for neutral stimuli. They also utilised the subsequent memory effect (otherwise known as the Dm effect, see 1.8.3 The Dm effect, Chapter 1), which is a very powerful neural index of encoding and found that this effect recording at encoding, was more positive going for subsequently remembered items compared to subsequently forgotten items. In addition to these broad effects of emotion and memory, the literature has outlined specific ERP components that are consistently found in studies using affective stimulus (for more details on known affective ERP components see 1.8.3 The Dm effect, Chapter 1; see Olofsson, Nordin, Sequeira & Polich, 2008 for review). One of the most prominent of these components is the late positive potential (LPP), which is a component characterised by a large positivity, particularly over parietal electrode sites, around 400-500ms after stimulus onset and lasting until around 800ms (Schupp et al., 2000; Schupp, Flaisch, Stockburger & Junghofer, 2006; Olofsson et al., 2008). This effect is widely thought to reflect sustained attentional response to emotional stimuli (Codispoti, Ferrari & Bradley, 2007; Olofsson et al., 2008), an interpretation that is broadly consistent with the effects of attention and emotional stimuli (Easterbrook, 1959; Loftus & Christianson, 1989; Christianson, 1991; Dolan et al., 2003; Kensinger, 2009). Examining these ERP effects can reveal details about the functional meaning of these patterns and highlight the cognitive processes (such as attention) involved, which facilitate the formation of emotional memories.

Combining the structural localisation of imaging studies with the temporal findings and cognitive processes that EEG studies have revealed, has greatly developed the field of research into emotion and overall it highlights the importance that neuroscience has had to uncovering the cognitive foundations of emotional processes.

1.8.3 The Dm effect

The Dm effect is defined as the differential neural activity based on memory (Paller & Wagner, 2002). It is also known as the subsequent memory effect and refers to the difference between neural activity of successfully encoded items and unsuccessful encoding of items. It is the contrast between these two types of activity that generate the Dm effect. The Dm effect acts as an neural index of encoding as has been widely used in memory research in both imaging (Otten & Rugg, 2001; Uncapher & Rugg, 2005; Blumenfeld & Ranganath, 2006) and ERP studies (Mangels, Picton & Craik, 2001; Dolcos et al., 2002;Duarte, Ranganath, Winward, Hayward & Knight, 2004; Otten, Sveen & Quayle, 2007).

Dm effects frequently reported in the literature have an onset around 400ms and have been cited as having both a centro-parietal (Fabiani et al., 1990) and a fronto-central (Friedman & Trott, 2000) topography. These effects have been interpreted as reflecting the attentional engagement of participants processing the information to a deeper meaning based level with enhanced elaboration, which leads to the information being encoded into memory (Paller & Wagner, 2002). This meaning based enhanced elaboration has been demonstrated in the literature, with items encoded to a deeper semantic level having an enhanced subsequent memory (Craik & Lockhart, 1972). Furthermore, when items are encoded to a deeper semantic level it has been shown to enhance these Dm effects (Otten et al., 2001; Otten et al., 2007), which supports the interpretation that this Dm effect reflects increased elaboration.

Although less common, Dm effects have also been reported occurring early before 400ms (Duarte et al., 2004) and later post 800ms (Mangels et al., 2001; Kim, Vallesi, Picton & Tulving, 2009). The early effects are thought to reflect early perceptual processes that engage attention and aid encoding (Mangels et al., 2001). The late Dm effects observed are thought to reflect the engagement of working memory processes, which can manipulate and maintain information to facilitate encoding (Mangels et al., 2001).

Research involving the Dm effect has also been applied to studies using affective stimuli. The literature outlines three main effects that are sensitive to emotional content, which are broadly compatible with known ERP components (Schupp et al., 2006). The first component often reported is the early posterior negativity (EPN). The EPN is generally occurs around 250-300ms after stimulus onset and is associated with a negative deflection over temporal-occipital electrode sites. This early effect is thought to involve the ‘natural selective attentional’ resources and is driven by approach and avoid motivations (Schupp et al., 2006; Olofsson et al., 2008). This engagement of early attentional resources would benefit encoding processes. The second main component affected by emotional stimuli, is the LPP. This is a late more positive going waveform for emotional items, often globally distributed, but with a posterior region maxima, occurring between 400-800ms (Schupp, et al., 2000; Schupp et al., 2006). It is thought that this effect is particularly sensitive to emotional arousal and reflects the attentional processing of stimuli and the engagement of working memory resources (Schupp et al., 2006; Codispoti et al., 2007; Olofsson et al., 2008). The last main effect often observed in studies using affective stimuli is the late positive slow wave. This is characterised by an extended late positive wave, often occurring post 800ms (Leutgeb, Schafer & Schienle, 2009). This component has been shown to be particularly sensitive to studies examining perceptual processes and memory systems (Schupp et al., 2006); therefore it has been suggested that this waveform reflects sustained attention to emotional stimuli and the maintenance and/or manipulation of information in working memory (Schupp et al., 2006; Olofsson et al., 2008).

These findings highlight how useful the Dm effect has been at uncovering the functional meaning of the patterns of activity associated with memory processes. This technique is now being applied to emotion and memory research to specifically uncover the neural activity associated in the encoding processes of emotional information, functionally examine the meaning of this activity and isolate the cognitive processes involved in the formation of emotional memories

1.9 Outstanding Questions

From the overview of the evidence presented above, there are several outstanding questions that are yet to be addressed by research in the literature. Although there is a large body of research highlighting the potential cognitive mediating factors that could play a role in the immediate EEM (Talmi & Moscovitch, 2004; Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012; Pottage & Schaefer, 2012), little research has been done to uncover the functional means by which these cognitive factors exert their influence in the immediate EEM. The research from Talmi and colleagues (Talmi & Moscovitch, 2004; Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) have set string behavioural foundations for the research into the formation of immediate emotional memories. This research, as mentioned above, has highlighted three key cognitive factors (distinctiveness, relatedness and attention) that play a significant role in the immediate EEM. However, the research into these factors has been predominantly behavioural and as such, the exact brain mechanisms that contribute to these factors playing a role are yet to be uncovered. In addition, the research has focused primarily on the three key factors outlined above; hence another outstanding question is how other factors such as arousal can influence the immediate EEM and if cognitive emotional processes (e.g. emotional regulation, working memory) can affect the immediate EEM.

1.10 Present research

This present study aims to examine several of the cognitive mediating factors implicated in the behavioural literature as playing a key role in the immediate EEM. Utilising the Dm effect technique explained above, this study aims to uncover the specific neural correlates associated with the encoding processes of emotionally negative information and then examine the functional meaning of these patterns of activity. This work will specifically target several cognitive factors to establish the role that they play as cognitive mediating factors in the immediate EEM. The study presented in Chapter 2 will address the conclusions of Talmi, Luk et al., (2007) and Talmi & McGarry (2012) and investigate the role that distinctiveness plays in the immediate EEM. By recording ERP data during this study, it is hoped that the functional mechanism through which distinctiveness exerts its influence, will be uncovered and a more complete understanding of this cognitive mediating factor will be developed. The study presented in Chapter 3 will be a replication of the study presented in Chapter 2, to ensure that the findings and conclusions of Chapter 2 are reliable. Furthermore, the study in Chapter 3 will also address some other measure of individual differences, which can influence emotion and memory interactions, such as emotional regulation processes. The work in Chapter 4 aims to address the outstanding question of how the factor of arousal can influence the immediate EEM; although this factor has been strongly implicated in the long-term formation of emotional memories, little research has been done to specifically examine how arousal influences the immediate EEM. The final study in Chapter 5 will address the conclusions from the studies by Talmi, Schimmack et al., (2007), Talmi, Luk et al., (2007 and Talmi and McGarry (2012), in regards to the role that semantic relatedness and attention play a role in the immediate EEM. The ERP data recorded during this study will aim to uncover the functional mechanism through which semantic relatedness affects the immediate EEM and how attention can interact and influence this relationship.

Chapter 2: The neural fate of neutral information in emotion-enhanced memory

2.1 Chapter Overview

The main goal of this study was to investigate the hypothesis that neural activity reflecting the encoding of emotionally *neutral* information in long-term memory is disrupted when neutral and emotional stimuli are intermixed during encoding. Participants studied negative and neutral pictures organized either in "mixed" lists (in which emotionally negative and neutral pictures were intermixed) or in "pure" lists (only-neutral or only-negative pictures), followed by a free recall test. To estimate encoding efficiency, we used the "Dm effect", measured with event-related potentials (ERP). Results showed that recall performance of neutral items was lower in mixed compared to pure lists and that an early (200-400) and a late (800-1500) Dm effect in posterior sites were cancelled for neutral items in mixed lists.

2.1.1 Introduction

Emotion-enhanced memory (EEM) refers to the well-known fact that emotional information tends to be better recalled than neutral information (Cahill & McGaugh, 1998; Schaefer & Philippot, 2005; Talmi et al., 2007; Pottage & Schaefer, 2012). This phenomenon has important implications for clinical and forensic psychology (Christianson & Loftus, 1987; Lanius et al., 2003; Brown et al., 2008) and has been the object of intense investigation for many years (LaBar & Phelps, 1998; Kensinger & Corkin, 2003; Dolcos et al., 2004; Johansson et al., 2004; Sharot et al., 2004; Talmi & Moscovitch, 2004; Mather, 2007; Talmi et al., 2007; Kensinger & Schacter, 2008; Koenig & Mecklinger, 2008; Weymar et al., 2009; Schaefer et al., 2011; Newsome et al., 2012; Talmi & McGarry, 2012). Several models suggest that the EEM effect is determined by a facilitation of plasticity in memory brain systems when emotional stimuli are encountered, thereby enhancing encoding efficiency for these stimuli (Brown & Kulik, 1977; Conway & Pleydell-Pearce, 2000; LeDoux, 2000). This simple principle has been supported by a wealth of research that has unveiled several patterns of brain activity specific to the encoding of emotional material. For instance, many studies indicate that amygdala-hippocampus interactions during the encoding of emotional information could explain the EEM phenomenon (LaBar & Phelps, 1998; Kensinger & Corkin, 2004; Dolcos et al., 2005). Although additional research has shown that the emotional modulation of consolidation and retrieval processes can also contribute to emotional memory (McGaugh, 2004; Sharot & Yonelinas, 2008), an influence of emotion at the encoding stage is still seen as a major determinant of EEM effects (Kensinger & Corkin, 2004; Kern et al., 2005; Talmi et al., 2007; Maddox et al., 2012).

However, the facilitation of encoding processes for emotional information might not be the only important factor determining EEM. One potential factor that has received less attention in the cognitive neuroscience literature is the role that *neutral* information plays in EEM. Some behavioural evidence suggests that EEM might be explained at least in part by a disruption of encoding efficiency for neutral information intermixed with emotional information. For instance, classical studies from the field of eyewitness memory showed that the recall of neutral peripheral information can be impaired when the central element of a scene is strongly emotional (Christianson & Loftus, 1987; Steblay, 1992). A more recent example comes from experiments that investigated the role of distinctiveness in the EEM effect. In these experiments, emotional and neutral stimuli are encoded either in "mixed" lists (when both types of stimuli are randomly intermixed) or in "pure" lists (lists of only emotional or only neutral items). Through this manipulation, emotional items are thought to be more distinctive in mixed than in pure lists, which typically leads to a stronger EEM in mixed lists (Dewhurst & Parry, 2000; Talmi & Moscovitch 2004; Schmidt & Saari, 2007; Talmi et al., 2007). Interestingly, an inspection of the results in some of these experiments (Dewhurst & Parry, 2000; Talmi et al., 2007) suggests that neutral stimuli tend to be better recalled in pure compared to mixed lists. In other words, recall of neutral information seems less efficient when it is intermixed with emotional stimuli, which can increase the effect size of the EEM effect.

An obvious explanation for this phenomenon could be linked to the well-known fact that we tend to allocate processing resources preferentially to emotional stimuli in the environment because they carry a strong motivational relevance (Bradley et al., 2001; Ohman & Mineka, 2001; Eimer & Holmes, 2007; Mermillod et al., 2010). By doing so, only scarce cognitive resources would be left to process less emotionally intense stimuli. Given that, in realistic environments, emotional and neutral information are usually intermixed, the latter would be encoded less efficiently because of a disadvantageous balance of processing resources. This explanation is broadly consistent with models used to account for the classical eyewitness memory experiments mentioned above (Loftus et al., 1987; Christianson, 1992). Specifically, these models contend that an emotional object in a given scene attracts attentional resources to the extent that less relevant objects in the periphery of the scene are "starved" of attentional resources, and therefore less efficiently encoded. This explanation is also consistent with evidence that the EEM is mediated by an asymmetrical balance of processing resources between emotional and neutral stimuli (Talmi et al., 2007; Pottage & Schaefer, 2012).

Although the behavioural evidence and theoretical models reviewed above clearly indicate that a disruption of encoding processes for neutral items might play a key role in EEM effects (see also Schmidt, 2002; Strange et al., 2003), the specific mechanisms underlying this disruption are still largely unknown. Indeed, successful encoding can be determined by multiple processes that are often difficult to disentangle. For instance, encoding is known to be influenced, amongst other factors, by early "quick" forms of attention, by more controlled forms of attention, by working memory processes, by the depth of semantic processing, etc. (Otten & Rugg, 2002; Paller & Wagner, 2002; Rugg et al., 2002; Kern et al., 2005; Blumenfeld & Ranganath, 2006; LaBar & Cabeza, 2006; Otten et al., 2007). In the case of emotion-enhanced encoding, this issue is particularly relevant because existing evidence is mixed regarding what types of cognitive processes modulate EEM at encoding (Pottage & Schaefer, 2012; Talmi, 2013).

The main objective of this study was therefore to examine the specific mechanisms underlying this emotion induced disruption of encoding for neutral information. To attain this goal, we first conducted a behavioural pilot study to ascertain if the mixed versus pure list paradigm, used in previous behavioural studies (Dewhurst & Parry, 2000; Talmi et al., 2007), does indeed reflect the cognitive factor of distinctiveness, which this study aims to examine. We predicted the behavioural pilot study would observe an impairment of performance for neutral items in mixed lists, similar to the effect observed in other studies and confirm the paradigm as a useful tool to study this effect. Based on the results of the behavioural pilot study, in order to examine more precisely the mechanisms underlying this effect, we then completed a full study using the same paradigm with EEG recordings. Using EEG and the Event-Related potentials method (ERP), we were able obtain the Dm effect and examine precisely the mechanisms underlying the emotion induced disruption of neutral information. As explained below, the Dm effect measured with ERPs is a well-known index of successful encoding that can provide information on the relative activation of distinct encoding processes. Therefore, it can be a useful tool to examine which specific processes are involved in the emotion-driven impairment of neutral information encoding.

The “Dm” effect ("Differential neural activity based on memory", Paller & Wagner, 2002) or “subsequent memory effect” is a difference between neural activity reflecting successful vs. unsuccessful encoding of information in memory. More specifically, item-related neural activity recorded at the time of encoding is separated according to whether each item is subsequently remembered or forgotten. The contrast between these two types of neural activity is the Dm effect (Paller & Wagner, 2002), a neural index of encoding processes which has been the object of intense investigation for many years (Paller et al., 1987; Buckner et al., 2000; Mangels et al., 2001; Rugg et al., 2002; Duarte et al., 2004; Reynolds et al., 2004; Blumenfeld & Ranganath, 2006; Otten et al., 2006; e.g., Gutchess et al., 2007; Voss & Paller, 2009; Bridger & Wilding, 2010). Studies using hemodynamic neuroimaging techniques tend to show that the Dm effect is typically linked to a network of brain areas including medial temporal and prefrontal areas (Rugg & Otten, 2002). Many ERP studies have reported a Dm effect typically characterized by a larger positivity for subsequently remembered compared to forgotten items (Paller & Wagner, 2002). This literature shows that the Dm effect can display different spatial and temporal properties across studies, which suggests that the Dm effect reflects the existence of multiple encoding processes (Friedman & Johnson, 2000; Paller & Wagner, 2002; Otten et al., 2007). The most frequently reported characteristics of the Dm effect in the ERP literature include an onset at approximately 400 ms and a fronto-central topography (e.g. Friedman & Trott, 2000; Otten et al., 2007), although certain studies report a centro-parietal distribution (Fabiani et al., 1990). This effect has been consistently interpreted as reflecting an attentional engagement leading to an enhanced elaboration of the meaning of the information being encoded (Paller & Wagner, 2002). A typical effect supporting this interpretation is that this effect is enhanced when participants are led to process information at a deeper semantic level compared to a shallow (e.g. orthographic) level of processing (Paller et al., 1987; Friedman et al., 1996; Otten & Rugg, 2001; Otten et al., 2007). In young adults, the Dm effect is also stronger when retrieved items are recollected rather than just familiar, which is broadly consistent with the interpretation that it reflects deeper elaborative processes at encoding (Friedman & Trott, 2000; Duarte et al., 2004; Voss & Paller, 2009). However, other Dm effects have also been reported in the literature. More particularly, early Dm effects prior to 400 ms have been reported (Duarte, 2004; Otten et al., 2007), and found to be sensitive to divided attention tasks (Mangels et al., 2001). These early effects have been interpreted as the manifestation of early attentional and perceptual processes that benefit encoding. Furthermore, late sustained Dm effects have also been observed approximately between 800 and 2000 ms on frontal and posterior sites (Mangels et al., 2001; Otten & Rugg, 2001; Caplan et al., 2009; Kim et al., 2009). This effect appears to be modulated by encoding conditions that are particularly demanding and likely to recruit working memory (WM) processes (Caplan et al., 2009). Accordingly, this late Dm effect has been consistently interpreted as reflecting sustained activation of information in working memory (Caplan et al., 2009; Mangels et al., 2001). This interpretation is consistent with usual interpretations of similar late sustained slow waves which are thought to reflect maintenance and/or manipulation of information in WM (Ruchkin et al., 1988; Revonsuo & Laine, 1996; Garcia-Larrea & Cezanne-Bert, 1998). A few ERP studies have tested the effects of emotional content on Dm activity (e.g. Dolcos & Cabeza, 2002; Righi et al., 2012). These studies have focused on whether the Dm effect for emotional stimuli conforms to ERPs known to be associated to the processing of emotional stimuli. Specifically, there are 3 main categories of ERPs that are sensitive to affective pictures: First, early ERPs (taking place approximately before 400 ms) are widely thought to reflect stimulus-driven selective attention whereby attentional resources are selectively attracted by the evolutionary and/or motivationally-relevant properties of emotional stimuli (Schupp et al., 2006; Olofsson et al., 2008; Walker et al., 2011). Second, a late positive potential (LPP) has often been observed, and it is thought to reflect post-perceptive attentional responses that are more sustained in time and for which the involvement of controlled processes would be greater (Codispoti et al., 2007; Olofsson et al., 2008). The LPP is characterized by a larger positivity for emotional compared to neutral pictures, and it is often widely distributed across the scalp with maxima in posterior sites. Although time windows used to measure it may vary across studies, it tends to be predominant between 400 and 800 ms (Codispoti et al., 2012). Third, sustained slow waves have also been observed in response to affective pictures and at times labelled "Late LPP" at latencies ranging approximately from 800 to at least 1500 (Leutgeb et al., 2009; Schienle et al., 2011) and beyond (Diedrich et al., 1997), and they might reflect sustained attentional processes linked to the maintenance of information in working memory, manipulation of information in WM, and/or encoding in long-term memory (Olofsson et al., 2008; Schupp et al., 2006).

The few ERP studies that tested the effects of emotional content on the Dm effect found an enhancement of Dm activity in time windows and scalp locations compatible with the LPP (Dolcos & Cabeza, 2002; Righi et al., 2012), suggesting that attentional engagement towards emotional stimuli is a reliable predictor of EEM effects. These studies provide invaluable insights into the neural and cognitive mechanisms underlying the emotion-enhanced memory effect (EEM). However, important outstanding questions remain: Notably, it is still largely unknown whether the emotional modulation of the Dm effect reflects an enhancement of the Dm effect for emotional compared to neutral items, or if it reflects, at least in part, an inhibition of encoding processes for neutral stimuli in the presence of emotional stimuli. In addition, although a number of behavioural studies have tested the effects of item distinctiveness (pure vs mixed list manipulation) on the EEM, and at least one fMRI study has investigated the EEM when only pure lists were used (Sommer et al., 2008), no published ERP study has yet examined Dm activity for emotional and neutral items across mixed and pure lists.

In summary, the main goal of this study was to use the ERP technique to examine the determinants of the emotion-induced impairment of memory for neutral items observed in previous behavioural data. In this study, our participants took part in an intentional encoding task in which they had to study a series of emotionally negative and neutral pictures while their scalp EEG was recorded.

Pictures were encoded in several lists of 24 pictures that were either pure (lists made of only emotionally negative or only neutral pictures) or mixed lists (where emotionally negative and neutral pictures were randomly intermixed). Event-related potentials were obtained for encoding-related activity according to whether pictures were subsequently remembered or forgotten to obtain the Dm effect. We first hypothesized that recall performance for neutral items would be lower in mixed compared to pure lists. Accordingly, we also predicted that Dm activity should be reduced or cancelled for neutral items in mixed lists. In addition, we expected that the spatial and temporal properties of the expected changes in Dm activity should be informative of the specific processes determining why neutral information encoding seems impaired in the presence of emotional information. Specifically, we targeted three main Dm effects: Pre-400 Dm effects, a predominantly frontocentral Dm effect with an onset at ~400 ms and a late slow wave ("late LPP") which should be more salient after 800 ms. According to the literature mentioned above, these ERP effects could suggest the involvement of (1) early attentional processes aiding encoding; (2) Enhanced semantic processing; (3) Temporally sustained attentional processes involving maintenance and/or manipulation of information in WM.

2.1.2 Aims

- To complete a behavioural pilot study, to ensure the experimental paradigm used is measuring the effects of distinctiveness and the emotion induced disruption of neutral information.
- To complete a full EEG study utilising the behavioural paradigm and the Dm effect to precisely examine the underlying neural correlates of neutral information in the EEM
- We expect to find an impaired recall performance of neutral items when they are presented in a mixed list condition
- We expect to observe a reduced Dm effect for neutral items presented in a mixed list condition, reflecting the behavioural recall results.

2.2 Behavioural Pilot Study

2.2.1 Methods of behavioural pilot study

2.2.1.1 Participants

Thirteen (4 Males) healthy adults, with a mean age 20.87 years (SD = 3.18 years) from Durham University, with no history of psychiatric or neurological conditions, took part in this study in exchange for course credits. All participants gave informed consent, which explicitly mentioned that they will be viewing images that some people may find potentially graphic and disturbing, to comply with the ethical guidelines of the study. Participants first completed two screening questionnaires, due to negative nature of the stimuli used in the study; any participants who scored above 21 on the Beck's Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) or those who scored above 50 on State Trait Anxiety Inventory (Speilberger, Gorsuch & Lushene, 1970) were excluded from the participating in the study.

2.2.1.2 Stimuli and Design

The study used realistic colour images, showing either emotionally negative or neutral scenes. There were 384 images used in total; with 281 images obtained for the International Affective Picture System (IAPS) (Bradley & Lang, 1994; Lang, Bradley & Cuthbert, 2005) and 103 added from Google Image™. Images were added from Google Image™ to ensure picture sets were matched for the presence of key non-emotional features, such as humans, animals and objects (Yamasaki, LaBar & McCarthy 2002; Dolcos, LaBar & Cabeza, 2004). All images were resized to a 455 x 342 pixel format and displayed centrally at 1024 x 768 pixels, on a computer screen. The images were all previously rated for valance and arousal (Schaefer et al., 2011; Pottage & Schaefer), using a 5-point version of the Self-Assessment Manikin (SAM): whereby Valence was rated as 1 = negative, 5 = positive; Arousal was rated as 1 = low, 5 = high arousal (Bradley & Lang, 1994). From these ratings the images were divided into emotionally negative and neutral subsets: with 192 negative (mean valence = 2.0; mean arousal = 3.22) and 192 neutral (mean valence = 3.18; mean arousal = 1.95) images. Both the valence and arousal dimensions were significantly different for each subset ($p < .001$). Using the arousal rating, the 192 emotionally negative images were then divided into subsets of high-arousal and low-arousal images; with 96 high-arousal images (mean arousal = 3.64) and 96 low-arousal images (mean arousal = 2.80). All negative images were balanced for the presentation of high and low arousal images, according to these ratings.

The images were divided into a mixed and pure list paradigm; whereby, half of the images were presented in mixed lists (intermixed emotionally negative and neutral images) and half were presented in pure lists (only emotionally negative images or only neutral images). The pure list condition contained 8 lists of images, presenting 24 pictures in each list. The images were blocked according to emotional valence (i.e. 4 blocks containing all emotionally negative images and 4 blocks containing all neutral images). The mixed list condition again contained 8 lists, with 24 images presented in each list. The images in these lists were randomly intermixed; with each list containing 12 negative and 12 neutral images. All 16 lists were presented to each participant and were grouped by condition; so all mixed lists were presented together and all pure lists were presented together. The order of presenting the mixed list condition first and the pure list condition second (and vice versa) was counter balanced across participants, with the list presentation within each condition fully randomised. All pictures were presented centrally on a white computer screen with a resolution of 1024 X 768 pixels, using E-Prime software for both data presentation and collection. The arithmetic test materials were obtained off of the internet and consisted of simple addition, subtraction, division and multiplication tasks.

2.2.1.3 Procedure

All participants studied the images sat on a chair approximately 70cm away from the computer screen and all images were displayed on screen using E-Prime 2.0 (Psychology Software Tolls, Pittsburgh, PA). Each block started with a fixation screen of a small black asterix displayed centrally on a blank white screen for 600ms (see Figure 2.1), followed by the image, which was displayed for 1500ms and given 100% width and height. After the display of every image, participants were required to make a valence response rating on a 5-point version of the Self-Assessment Manikin (SAM, Bradley & Lang, 1994), by pressing the corresponding numbers (1-5) on the computer keyboard. Participants could take as long as needed to make the valence rating and once they had responded there was a blank white screen presented for 800ms, before the onset on the next trial.

After every block of 24 images (24 trials, as described above), participants were required to complete a simple metal arithmetic task for 90 seconds; this aimed to minimise the possibility of any rehearsal of the images between the encoding and recall phase. The arithmetic task consisted of simple maths problems and participants were requested to solve as many problems as accurately as possible in the allocated time. Participants' memory was then tested using free-recall, following Bradley, Greenwald, Petry, & Lang's (1992) procedure. Free recall is not as typically used in pictorial studies compared to memory recognition tests however it has been successfully used in many previous studies which involve memory and emotion (Blake, Varnhagen, & Parent, 2001; Bradley et al., 1992; Palomba, Angrilli, & Mini, 1997). Free-recall is also more akin to real-life situations, hence more ecologically valid (Talmi, Luk et al., 2007). Participants were given up to 5 minutes to recall as many of the images as they could remember form the block they had just viewed, by writing down descriptions by hand; they were instructed to keep descriptions succinct using the following instructions:

You now have around 5 minutes to recall as many of the images that you have just seen. Please be exact and succinct in your descriptions, using only 3 or 4 main words for each picture, avoiding long sentences. If there are any ambiguous descriptions the experimenter will ask you to clarify at the end of the study. If you are unsure of any descriptions of the images, please do include them too, even if you feel you are just guessing.

All participants were well practised and performed 10 practice trials following the above format (displaying images similar to what the experiment would present) and were given the opportunity to ask any questions, in order to familiarise themselves with the experimental procedure before beginning the recorded trails. The experimenter coded the images for matches and non-matches, asking participants to elaborate on any ambiguous descriptions to avoid the potential confusions Bradley et al. (1992) highlighted. Just as the Bradley et al. study it was found that almost all descriptions were clear and straightforward to match.

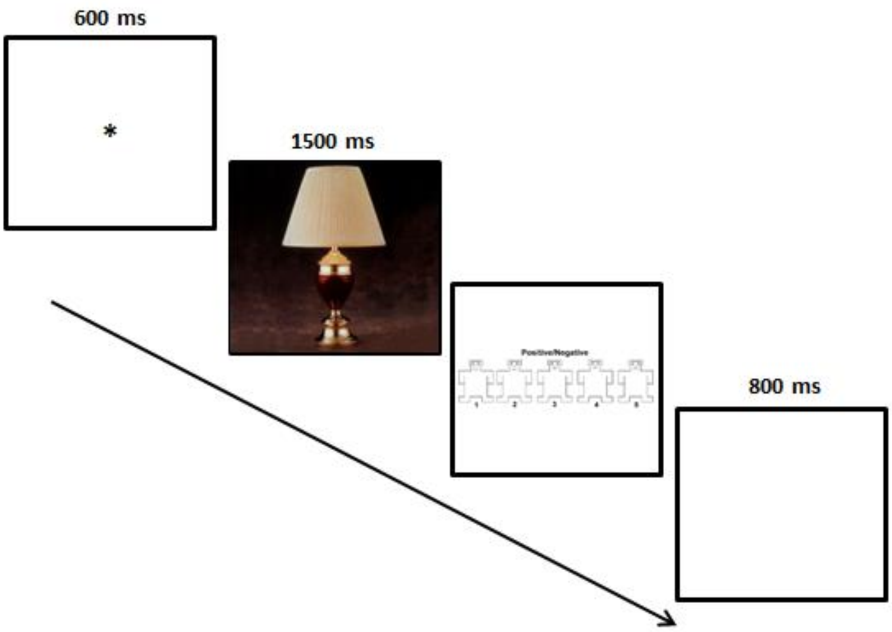

Figure 2.1: Schematic representation of the experimental trial procedure.

2.2.2 Results Behavioural Pilot

As expected, the pilot study results show an initial trend for the difference between the amount of negative and neutral images recalled in the mixed list condition to be greater than in the pure list condition (see Figure 2.2). The highest level of recall was recorded for negative items in the mixed list condition (mean = .43), compared to a reduced level of recall for neutral items in the mixed list condition (mean =.27). The pure-list condition also had a higher level of recall for negative items (mean = .37), compared to the pure neutral recall rate (mean = .30)

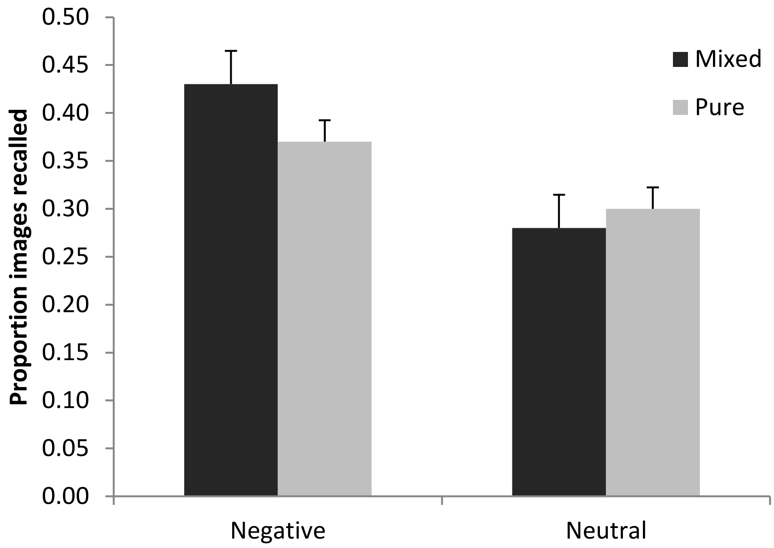

Figure 2.2: Mean recall rate by list-type condition and Emotion. Error bars represent standard error of the mean.

Conducting a 2 X 2 ANOVA, using list-type and emotion as factors, revealed as expected a significant main effect of emotion [$F(1, 12) = 30.675$, $p < .001$, $\eta p^2 = .719$], reflecting the higher recall rates for negative items compared to neutral items. Although there was no significant main effect of list-type ($F < 1$) there was a significant interaction between list-type and emotion [$F(1, 12) = 15.667$, $p = .002$, $\eta p^2 = .566$]. Pairwise comparisons revealed this interaction was driven by the proportion of negative images recalled compared to neutral images in the mixed list condition, was significantly higher than the proportion of negative images compared to neutral images recalled in the pure list condition [$t(12) = 3.989$, $p = .002$]. The difference between the recall rates of negative and neutral items in the mixed list condition, compared to the pure list condition, suggests that neutral items may have a reduced recall rate in the mixed list condition. These initial results firmly suggested that this paradigm is effective at identifying important differences between the recall of images between the mixed and pure list condition and taps into the cognitive effects of distinctiveness in EEM. We can therefore be confident that using this paradigm in a comprehensive study using EEG recordings will uncover the neural correlates of this complex interaction.

2.3 Methods EEG study

2.3.1 Participants

Thirty-four healthy right-handed adults (25 females, mean age 23.18 years, SD = 6.66) from Durham University or the surrounding community, with no history of neurological or psychiatric disorders, completed the study in exchange for course credits or were remunerated for their time (£20). All participants gave informed consent, and the study was approved by the local ethics committee. Seven participants were excluded from the analysis: Six participants did not have enough artifact-free trials in at least one relevant condition, and one participant was deemed as a behavioural outlier, as his recall performance was above 3 SDs from the sample mean. This left a final sample of 27 participants (19 females, mean age of 24.04 years, SD = 7.23).

2.3.2 Stimuli and Design

The stimuli used were realistic pictures showing emotionally negative and neutral scenes obtained mainly from the International Affective Picture System (IAPS), (Bradley and Lang, 1994; Lang et al., 2005). Similar to other studies (Yamasaki et al., 2002; Dolcos et al., 2004; 2004), similar pictures taken from Google Image™ were added to the IAPS set to ensure that emotional and neutral sets of pictures were matched for key non-emotional dimensions (presence of humans, animals and objects; see appendix G). A total of 480 images were shown to participants across all picture sets: 359 IAPS and 121 from Google Image™. All the images were resized to a 455 x 342 pixel format and displayed centrally at 1024 x 768 pixels on a 40 cm x 30 cm Samsung SyncMaster computer screen (TCO’03 Displays, MagicBright). All images were previously rated for valence and arousal using a 5-point version (Valence: 1 = negative, 5 = positive; Arousal: 1 = low, 5 = high) of the Self-Assessment Manikin (Bradley and Lang, 1994) on a sample of British students similar to the participants used in the present study (Schaefer et al., 2011; Pottage and Schaefer, 2012). From these ratings, the images were divided into emotional (i.e. emotionally negative) and neutral picture sets, with 240 emotional images (mean valence score: 2.0, SD = 0.4; mean arousal score: 3.2, SD = 0.5) and 240 neutral images (mean valence score: 3.2, SD = 0.3; mean arousal score: 1.99, SD = 0.4). Emotional and neutral picture sets were significantly different from each other for both valence and arousal ratings (*p*s<.001). In order to perform complementary analyses in terms of arousal levels (see Methods), we also divided the set of emotionally negative pictures into a high and a low arousal group through a median split. Mean arousal scores differed significantly ($p<.001$) between high and low arousal picture groups (low arousal: Mean =2.82, SD =0.26; high arousal: Mean =3.63, SD =0.36,). As stated above, picture sets were carefully arranged so that the frequencies of non-emotional characteristics presence of humans, presence of objects and presence of animals) were kept similar across emotional and neutral sets. In addition, we verified that emotional and neutral pictures were not significantly different in low-level picture properties. Picture properties (brightness, contrast and spatial frequency) were extracted for each picture using MATLAB following the approach used by Bradley et al. (2007). Brightness was defined as the mean red, green and blue intensity for each pixel averaged across all pixels in the picture. Contrast was obtained in two steps: First, the standard deviation of pixel intensities in each image column was computed; then the standard deviation across all image columns was computed. The latter was used as an index of contrast. Spatial frequency was obtained in three steps: First a power spectrum of the image was computed; then the frequency that split the area under the power spectrum in two equal halves was obtained for each row and for each column of the image; finally, these median-split frequencies were averaged across all rows and columns. This average was used as an index of the dominant spatial frequency in the picture. Emotional and neutral pictures did not differ significantly in any of these measures (all *p*s > .09).

All images were divided into 10 mixed and 10 pure lists of 24 pictures. Five pure lists contained only emotionally negative pictures and the remaining 5 pure lists contained only neutral pictures. Mixed lists and negative pure lists contained each an equal amount of high and low negative arousal pictures. In addition, half the participants saw all the mixed lists first followed by all the pure lists and vice-versa for the other half of the sample. The order of negative / neutral lists within the pure lists was also counterbalanced and the order of the pictures within each list was randomized. Finally, picture contents were alternated between mixed and pure lists (i.e., the pictures used in mixed lists for half of the samples were used in pure lists for the other half of the sample).

2.3.3 Procedure

Participants sat in a comfortable armchair at approximately 70 cm from a 19” CRT screen on which the stimuli were displayed. E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA) was used to display the stimuli on the screen, and the accuracy of the synchronization between the onset of each visual stimulus on the screen and a trigger signal received by the EEG system was established using the BlackBox Toolkit (BlackBox Toolkit Ltd, York, UK), a system that uses photosensitive diodes to measure the timing of display stimuli on a screen. For each trial, a fixation (small black asterisk) was displayed centrally on a white screen for 600 ms, followed by a neutral or emotionally negative picture, displayed for 1500 ms. Each display image was centred on the screen and given 100% width and height with any remaining screen space displayed white. After the display of every image, participants were asked to rate the emotionality of the picture on a 5-point version of the Valence Self-Assessment Manikin (1=Positive, 5=Negative) using a response box. Finally, a blank screen was displayed for 800 ms (see Figure 2.1). Before the experiment, participants performed a series of 10 practice trials in order to get familiarized with the procedure. Participants were given the opportunity to ask questions if any instructions were unclear before the experiment began. At the end of each block of 24 pictures, participants were asked to perform an arithmetic task lasting 90 seconds in order to minimize rehearsal between the study and test stages. The task was a series of arithmetical problems which participants had to answer on paper by hand. The questions consisted of simple addition, subtraction, multiplication and division calculations. Participants were encouraged to solve correctly as many of the questions as they could in the allocated time.

After the arithmetical tasks, participants were given up to 5 minutes to recall as many pictures as possible from the list that they had just studied, although most participants did not need to use the full 5-min period. Participants were asked to write down a brief description of each picture that they recalled according to the following instructions:

"*You now have around 5 minutes to recall as many of the images that you have just seen. Please be exact and succinct in your descriptions, using only 3 or 4 main words for each picture, avoiding long sentences. If there are any ambiguous descriptions the experimenter will ask you to clarify at the end of the study. If you are unsure of any descriptions of the images, please do include them too, even if you feel you are just guessing.*"

Similar to previous research (Pottage & Schaefer, 2012) we used a liberal recall criterion to maximize the number of recalled items. Previous evidence shows that a liberal criterion increases the amount of accurate information retrieved during memory tests (Wright et al., 2008).

2.3.4 Memory Coding

Participants' descriptions of each remembered picture were coded independently by two researchers following previously established methods (Bradley et al., 1992; Talmi et al., 2007; Pottage & Schaefer, 2012). Similar to previous studies, agreement between coders was high (97%). To prevent the probability of false positives (false memories coded as true), we followed procedures developed in our previous work (Pottage & Schaefer, 2012): only descriptions that allowed both identification of the image and differentiation from other images in the block were coded as true memories. Descriptions that were too vague to allow identification or descriptions that allowed identification but no clear differentiation between similar pictures were not counted as true memories. Disagreements between coders were resolved by taking a conservative interpretation of the rules described above.

2.3.5 Electrophysiological data recording and processing

Scalp electrophysiological activity (EEG) was recorded from a 64-channel cap (Waveguard, ANT Inc., Enschede, Netherlands) at a rate of 512 Hz (DC-138 Hz bandwidth) and an impedance < 20 kS (although most electrodes had an impedance < 10 kS). EEG data was recorded using an average reference and digitally converted to a linked mastoids reference. EEG data was analysed using the ERP module of BESA 5.3 (MEGIS software GmbH, Grafelfing, Germany). Data were filtered offline (0.03-30 Hz), corrected for eye movements (Berg & Scherg, 1994), segmented into epochs between 100 ms before and 1500 ms after stimulus onset and baseline corrected. For each channel, we rejected epochs which had a difference between the maximum and minimum voltage amplitudes exceeding 120 µV or a maximum difference between two adjacent voltage points above 75 µV (after eye-movement artifact correction). ERP waveforms were created through averaging EEG data for Remembered trials (items that were successfully recalled) and Forgotten trials (items that were not recalled) separately for the mixed list condition and the pure list condition and for neutral or negative items, resulting in eight trial types: mixed-negative-remembered, mixed-negative-forgotten, mixed-neutral-remembered, mixed-neutral-forgotten, pure-negative-remembered, pure-negative-forgotten, pure-neutral-remembered, pure-neutral-forgotten. We excluded participants who contributed fewer than 12 artifact-free trials for at least one of these conditions (see Participants section). This criterion is consistent with many previous ERP studies on memory processes (Azimian-Faridani & Wilding, 2006; Kim et al., 2009; Gruber & Otten, 2010; Galli et al., 2011; Padovani et al., 2013). The mean number of artifact-free trials per condition was: 39.85, 69.07, 26.41, 79.04, 38.19, 70.11, 33.22 and 73.74, respectively.

2.3.6 ERP data analysis

2.3.6.1 Selection of time windows and scalp locations

We extracted mean amplitudes in three time windows (200-400, 400-800, 800-1500) selected on the basis of a careful visual inspection of our waveforms, and on the basis of previous research on both the Dm effect and ERPs to affective pictures, briefly outlined in the Introduction section. Specifically, we wanted to target 3 ERP effects: First, we chose a 200-400 time window which would cover early Dm effect observed in previous research (e.g. Duarte et al., 2004; Mangels et al, 2001), while overlapping with time windows where early ERPs to emotional pictures can usually be observed (Walker et al., 2011; Olofsson et al., 2008). Next, we wanted to target two sustained Dm effects that have an onset after 400 ms. Previous literature has reported Dm effects starting at ~400 ms (e.g. Dolcos & Cabeza, 2002; Friedman & Trott, 2000) and Dm effects starting at later latencies compatible with slow waves (e.g. Caplan et al., 2009; Mangels et al., 2001). A similar distinction was observed in the literature of ERPs to affective pictures, where a late positive potential (LPP) has often been observed in latencies covering a 400-800 time window (Codispoti et al., 2012), whereas a sustained slow wave sometimes called "late LPP" has been previously isolated in an 800-1500 time window (Leutgeb et al., 2009; Schienle et al., 2010). This time window also corresponds to time windows often used to quantify slow wave effects in the literature of ERPs linked to attention and working memory (e.g. Rushkin et al, 1988). Therefore, we chose two additional time windows which should cover the latencies of these two effects: 400-800 and 800-1500.

As explained in the introduction, previous research has revealed that the Dm effect can be observed in fronto-central or centro-parietal locations, depending on a series of factors such as the type of task, materials used and specific Dm subtype being examined. Therefore, we selected six scalp regions spanning anterior (fronto-central) and posterior (centro-parietal) regions and left, midline and right sites: Left Anterior (F7, F5, F3, FT7, FC5, FC3), Midline Anterior (F1, Fz, F2, FC1, FCz, FC2), Right Anterior (F8, F6, F4, FT8, FC6, FC4), Left Posterior (P7, P5, P3, TP7, CP5, CP3), Midline Posterior (P1, P2, Pz, CP1, CP2, CPz) and Right Posterior (P8, P6, P4, TP8, CP6, CP4). Next, similar to previous research (Curran et al., 2006; Schaefer et al., 2011; Walker et al., 2011), we averaged data for single electrodes inside each of these ROIs. This practice has been recommended to address familywise error in dense arrays of electrodes (Oken & Chiappa, 1986).

2.3.6.2 Statistical analysis

For each time window (200-400, 400-800, 800-1500), a repeated-measures ANOVA was computed on mean amplitude data including the following factors: (1) Memory (Remembered vs. Forgotten), (2) Emotion (Negative vs. Neutral), (3) List (Mixed vs. Pure), (4) A-P (Anterior- Posterior), and (5) Laterality (Left, Midline and Right). For conciseness, and given our focus on the Dm effect, we preferentially targeted effects involving the Memory factor. Given that our hypotheses suggest that Dm activity should be cancelled (or at least reduced) in mixed lists, and that this effect should be specific to neutral items, our main expectation was to obtain statistical effects involving an interaction between Memory, List and Emotion. Relevant effects involving the Memory factor were followed up with subsidiary ANOVAs up to the level of Remember vs. Forgotten pairwise comparisons. Finally, we compared the scalp distributions of observed effects using Remembered – Forgotten difference scores normalized according to the Max-Min Method (McCarthy & Wood, 1985). This analysis is explained in more detail in the “Topographical Analyses” section. For all the analyses, results were considered reliable at $p \leq 0.05$, and partial eta-squares were reported in order to provide estimates of effect sizes.

2.3.7 Controlling for arousal

An additional analysis was performed to establish that Dm effects obtained with negative items were not a spurious effect stemming from a confound between the Dm effect and the effect of arousal on ERP amplitude. Previous research has shown that arousal is linked with an overall increase in ERP positivity (Schupp et al., 2000; Codispoti et al., 2007). Therefore, a positivity for "Remembered" emotionally negative items compared to "Forgotten" emotionally negative items could just reflect the possibility that subsequently remembered items are more arousing than subsequently forgotten items. A potential method to address this possibility is to recalculate the Dm effect in subgroups of stimuli which have a more homogenous level of arousal (i.e., high- and low-arousal subgroups). If the observed Dm effect for emotional items is accounted for mainly by differences in arousal, then the Dm effect recalculated within high- and low-arousal subgroups should both either be reduced or cancelled. In order to perform this analysis, we categorized our emotional stimuli into high- and low-arousal subgroups through a median split on the arousal scores available for each picture (see Methods section) and performed Remembered vs. Forgotten contrasts within each subgroup. These analyses were based on subsamples of 20 participants who had enough artifact-free trials for the high-arousal pictures and 15 participants for the low-arousal pictures. The mean number of artifact-free trials in the high-arousal condition was 23.75 (mixed) and 22.65 (pure) trials for remembered items and 29.90 (mixed) and 32.45 (pure) trials for forgotten items. In the low-arousal condition, the mean number of artifact-free trials was 20.27 (mixed) and 21.07 (pure) trials for remembered items and 33.93 (mixed) and 33.20 (pure) trials for forgotten items.

2.4 Results

2.4.1 Behavioural Results

The behavioural results expand upon the findings observed in the pilot study and show a definitive reduction on the recall rate of neutral items compared to the (mean = .25) compared to the mixed emotionally negative items (mean = .37). Furthermore, these results show similar levels of recall in the pure list condition, to the results observed in the pilot study, with the pure negative condition maintaining a higher level of recall (mean = .35) compared to the pure neutral condition (mean = .31).

An Emotion × List within-subjects ANOVA performed on recall rates revealed a main effect of Emotion [$F(1,26) = 78.0$, $p < .0001$, $\eta p2 = .75$] indicating that negative pictures were better recalled than neutral pictures. We also found an interaction between Emotion and List [$F(1,26) = 13.26$, $p < .001$, $\eta p2 = .34$]. Subsidiary analyses revealed that the effect of Emotion was significant for both mixed and pure lists, although the effect size was smaller for pure lists [$F(1,26) = 56.7, 15.0$, *p*s < .001, $\eta p2 = .69, .37$]. We also found that the effect of List was significant for neutral items [$F(1,26) = 16.2$, $p < .001$, $\eta p2 = .38$] but not for negative items ($F < 1$). Consistent with our hypotheses, this effect was driven by a significant reduction of recall performance for neutral pictures in mixed compared to pure lists, as depicted in Figure 2.3.

2.4.2 SAM and Reaction Times

Analyses were also performed on SAM valence ratings taken during the study. The results revealed a main effect of Emotion [$F(1, 26) = 248.89$, $p < 0.0001$, $\eta p2 = .905$], indicating unsurprisingly that negative pictures were rated more negatively than neutral pictures (emotionally negative images: M=3.98, SD=0.30; neutral images: M= 2.56, SD =0.42). For completeness, we also analysed the response times associated to the SAM judgment task, but no significant effects were found (all *p*s >.10). This indicates there were no differences in the time taken to respond to the SAM scale, between any of the key four conditions.

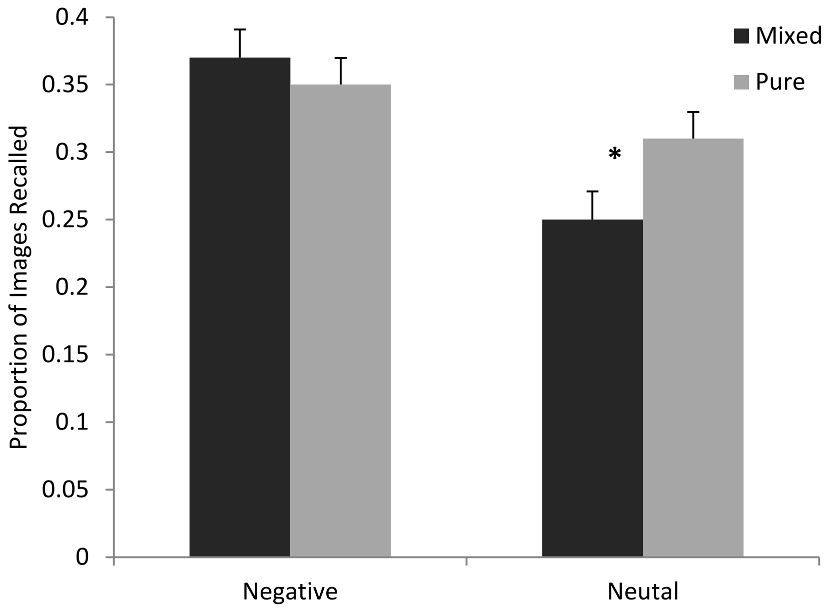

Figure 2.3: Mean recall rate by List-type and Emotion. Error bars represent standard error of the mean.

2.4.3 ERP Results

A visual inspection of Figures 2.4 a and 2.4 b indicates the presence of a robust overall Dm effect consisting of a strong differentiation between waveforms for subsequently remembered and forgotten items starting at ~300 ms and extending up to the end of the recorded epoch. Although this effect appears strong overall, the Dm effect appears to be diminished in the neutral-mixed conditions, specifically for posterior sites. A close examination of the posterior waveforms suggest that this reduction is the strongest in an early (pre-500) and a later sustained positivity (post-800), where the Dm effect appears to be cancelled. We describe hereafter the statistical analyses that tested whether this apparent cancellation of Dm activity in the neutral-mixed condition was reliable.

200-400

A general Emotion X Memory X List X A-P X Laterality ANOVA revealed a robust main effect of Memory [$F(1, 26) = 5.7$, $p = .02$, $\eta p2 = .18$] indicating an overall larger positivity for subsequently recalled compared to subsequently forgotten items. We also observed a complex interaction between Memory, List, Emotion and A-P [$F(1, 26) = 4.9$, $p = .03$, $\eta p2 = .16$]. In order to elucidate this interaction, we separated our data by Emotion (negative vs. neutral) and computed a subsidiary Memory X List X A-P ANOVA separately for emotionally negative and neutral items. For negative items, we found a main effect of Memory [$F(1, 26) = 4.6$, $p = .04$, $\eta p2 = .15$] consistent with the overall effect of Memory reported above, and no other interaction. For neutral items, we also observed a main effect of Memory [$F(1, 26) = 4.1$, $p = .05$, $\eta p2 = .14$] and a List × Memory × AP interaction [$F(1, 26) = 7.3$, $p = .01$, $\eta p2 = .22$]. This interaction was driven by a Memory × A-P interaction significant for mixed [$F(1, 26) = 6.0$, $p = .02$, $\eta p2 = .19$] but not pure lists [$F < 1$]. This Memory × A-P interaction in neutral-mixed conditions was driven by a significant effect of Memory in anterior [$F(1, 26) = 9.1$, $p = .006$, $\eta p2 = .26$] but not in posterior sites [$F < 1$]. In summary, these results indicate that the Dm effect in this time window appears to be robust across most conditions and sites except in the neutral-mixed condition, where Dm activity in posterior sites is cancelled.

400-800

Statistical analyses revealed a robust main effect of Memory [$F(1, 26) = 13.5$, $p = .001$, $\eta p2 = .34$] indicating an overall larger positivity for subsequently recalled compared to subsequently forgotten items. The interaction between Memory, List, Emotion and A-P observed in the other time windows did not reach significance in this time window. [$F(1, 26) = 1.1$, $p = .30$, $\eta p2 = .04$].

800-1500

A general Emotion X Memory X List X A-P X Laterality ANOVA revealed a main effect of Memory [$F(1, 26) = 11.6$, $p = .002$, $\eta p2 = .31$] indicating a larger positivity for subsequently recalled compared to subsequently forgotten items. Similar to the 200-400 time window, we found an interaction between Memory, List, Emotion and A-P [$F(1, 26) = 11.2$, $p < .002$, $\eta p2 = .30$]. In order to better understand this interaction, we computed subsidiary Memory X list X A-P ANOVAs separately for negative and neutral items. For negative items, we found a main effect of Memory [$F(1, 26) = 12.1$, $p = .002$, $\eta p2 = .32$] also reflecting a higher positivity for remembered items. For neutral items, we observed a smaller main effect of Memory [$F(1, 26) = 5.6$, $p = .02$, $\eta p2 = .18$] and a List × Memory × A-P interaction [$F(1, 26) = 6.4$, $p = .02$, $\eta p2 = .20$]. This interaction was driven by a Memory × A-P interaction significant for mixed [$F(1, 26) = 7.5$, $p = .01$, $\eta p2 = .22$] but not for pure lists [$F < 1$]. This Memory × A-P interaction in neutral-mixed conditions was driven by a significant effect of Memory in anterior [$F(1, 26) = 4.0$, $p = .05$, $\eta p2 = .13$] but not in posterior sites [$F < 1$]. Similar to the 200-400 time window, these analyses show that, although the Dm effect appears reliable across most sites and conditions, it is cancelled in posterior sites for the neutral-mixed condition. These analyses clearly show that the interaction between List, Emotion and Memory was driven by a cancellation of Dm activity for the neutral-mixed condition in posterior sites. However, a visual inspection of Figures

2.4a and 2.4b suggests two additional effects. First, although the Dm effect in pure lists seems to be robust across most conditions and sites, a close look at posterior sites (Figure 2.4b) suggests that the Dm effect in pure lists might be larger for neutral compared to emotional items. To examine this possibility, we tested a focused Memory X Emotion X A-P X Laterality exclusively on pure lists. We found a highly significant main effect of Memory [F(1, 26) =12.2, p=.002] but this effect did not significantly interact with Emotion or A-P, which rules out any reliable difference between negative and neutral items in pure lists. Second, the Dm effect for negative items in pure lists appears to be of a lesser strength compared to the same effect in mixed lists, especially in later stages of the epoch. To examine this possibility, we extracted mean amplitudes for the 1000-1500 time window for the Pz electrode. Using one-tailed *t*-tests to contrast Remembered vs. Forgotten amplitudes on this time window, we found that the Dm effect for emotionally negative items was significant in mixed [$t(26) = 2.0$, $p = .03$], but not pure lists [$t(26) = 1.1$, $p = .13$]. However, the List × Memory interaction was not significant; indicating that the difference between mixed and pure lists for negative items was not strong enough to be statistically reliable.

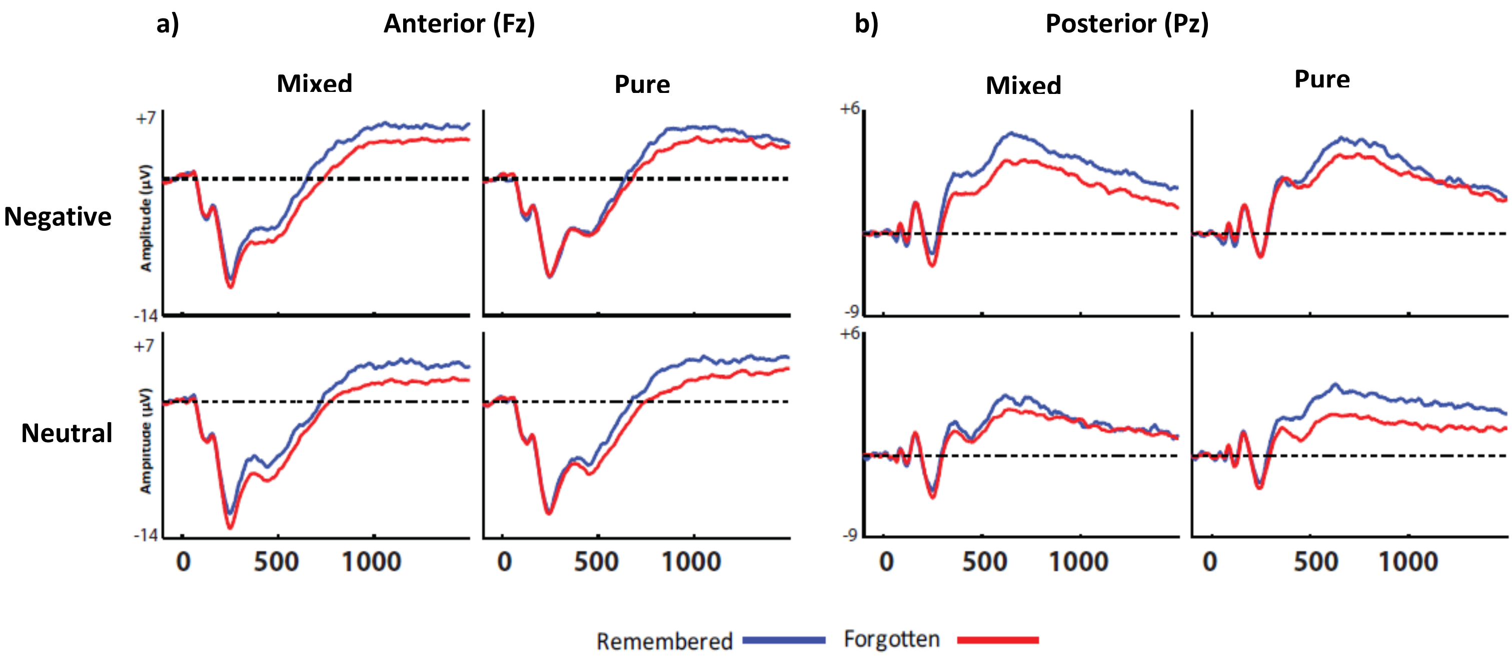

Figure 2.4 a) ERP waveforms plotted on electrode Fz for encoding-related activity separated according to subsequent memory (Remembered vs. Forgotten) and picture content (Negative vs. Neutral).Amplitude in microvolts (µV) is on the *y* axis and time in milliseconds is on the *x* axis. b) ERP waveforms plotted on electrode Pz for encoding-related activity separated according to subsequent memory (Remembered vs. Forgotten) and picture content (Negative vs. Neutral).

2.4.4 Topographical analyses

The analyses reported in the previous section indicate that the Dm effect for neutral items in mixed lists was mostly absent from posterior sites, resulting in a predominantly fronto-central scalp topography. This effect can be clearly seen in Figure 2.5. The same effect for emotional items appears to be more widely distributed, with sizeable effects observable across both anterior and posterior sites. These differences were observed in an early (200-400) and a late (800-1500) time window. In order to explore further these potential topographical differences, we created Dm difference scores (Remembered minus Forgotten) and we scaled these scores using the Min-Max range normalisation method (McCarthy and Wood, 1985). This method is often used in the field of ERPs of memory processes in order to compare the shape of ERP topographies controlling for potential confounds caused by amplitude differences between conditions (for detailed discussions of the strengths and weaknesses of this approach, see Haig et al., 1997; Ruchkin et al., 1999; Urbach and Kutas, 2002; 2006; Wilding, 2006). We computed a Latency (200-400 vs. 800-1500) × A-P X Laterality × List × Emotion ANOVA, and we found a significant List × Emotion × A-P interaction [$F(1, 26) = 10.6$, $p = .003$, $\eta p2= .29$] regardless of Latency. Subsidiary ANOVAs confirmed that this interaction was driven by a significant A-P × List interaction for neutral items [$F(1, 26) = 9.4$, $p = .005$, $\eta p2 = .26$], but not for emotionally negative items [$F < 1$]. This A-P × List interaction was driven by a significant effect of A-P for mixed lists [$F(1, 26) = 6.9$, $p = .01$, $\eta p2= .21$], but not for pure lists [$F < 1$]. These effects obtained on rescaled Dm difference scores confirm the significant Memory × List × Emotion × A-P interactions observed in the unscaled data, as well as the subsidiary Memory × List × A-P interactions found for neutral items. Therefore, these results do not indicate that the topographical differences revealed in the unscaled data might have been caused by confounds due to amplitude differences between conditions.

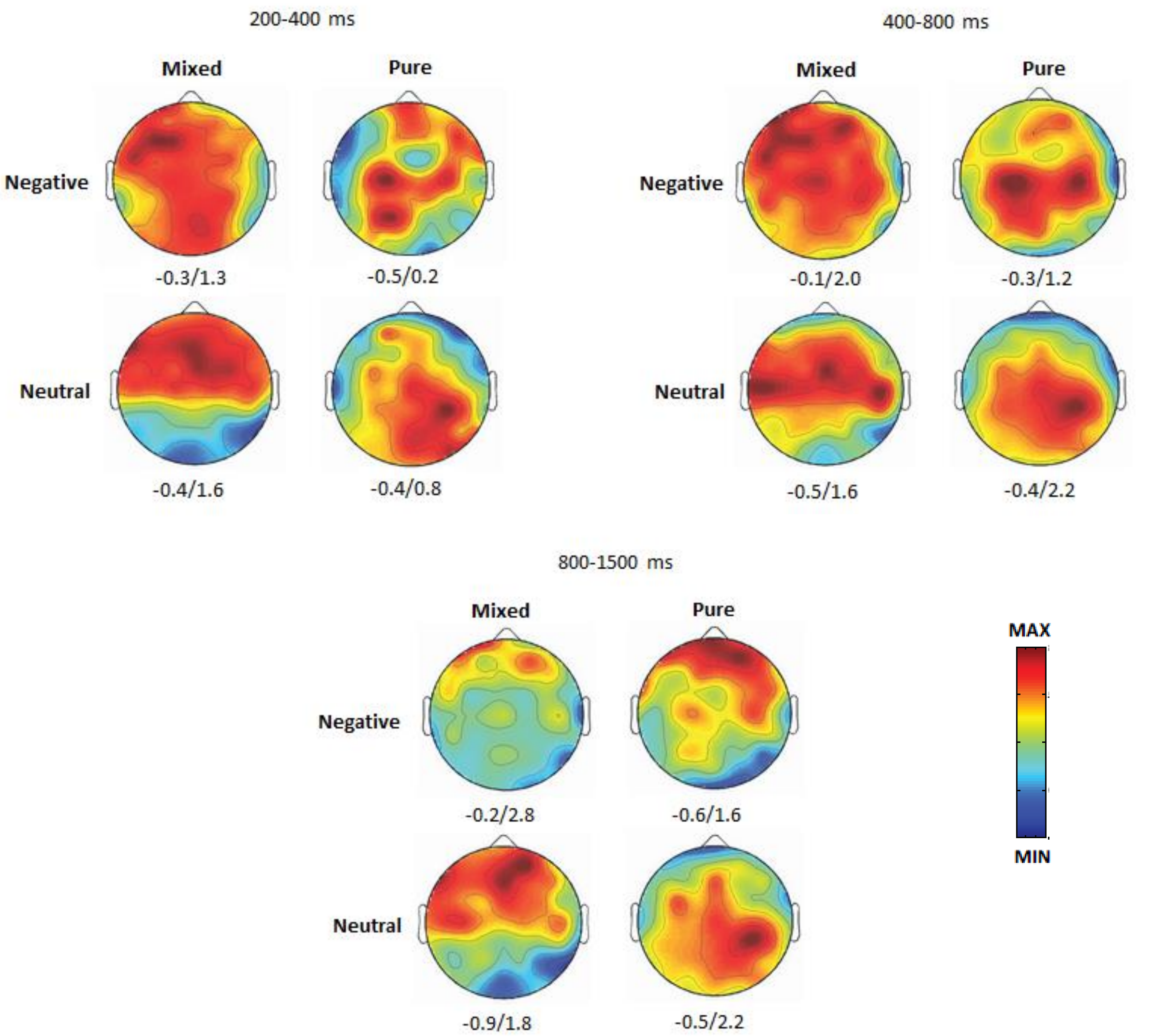

Figure 2.5: Two-dimensional scalp maps plotting "Remembered" minus "Forgotten" mean ERP amplitude difference scores. Numbers below each plot represent the maxima and minima, which are specific to each scalp map.

2.4.5 Controlling for Arousal

A series of Memory × Laterality × List × A-P ANOVAs showed a main effect of memory in all time windows for high-arousal emotional items [200-400, 400-800, 800-1500: $F(1, 19) = 6.0, 14.9, 16.8$; ps =.02, .001, .001; ηp^2= .24, .44, .47]. No effects involving Memory were significant for low-arousal emotional items. This result suggests that Dm effects observed for emotionally negative items are mainly accounted for by high-arousal items. In addition, the fact that the main effects of memory are significant in a subgroup of items with a greater homogeneity in arousal levels, and that these effects had a comparable effect size to the main effects of memory obtained in the main analysis, suggests that there is no evidence that the Dm effect obtained for negative items would be the result of an effect of a confound between arousal and subsequent memory (see Figure 2.6).

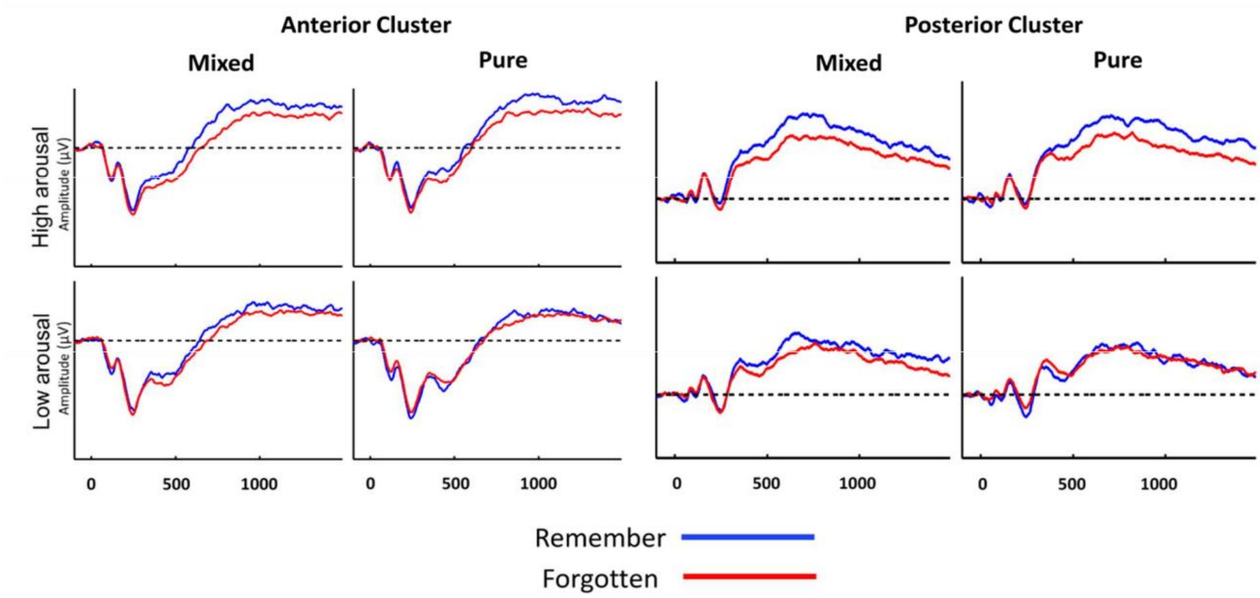

Figure 2.6: The Dm effect separately for high and low arousal groups at anterior and posterior electrode cluster sites.

2.5 Discussion

In this study, we observed an overall Dm effect reliable across most scalp sites and trial types, with a notable exception: when emotional and neutral items were intermixed, the Dm effect for neutral items was cancelled in posterior sites at an early (200-400) and a late (800-1500) time window. These results are consistent with our initial hypothesis and they converge with the behavioural results: recall performance for neutral items was lower in mixed compared to pure lists, whereas recall rate for negative items did not significantly differ between mixed and pure conditions. These results fit with the hypothesis that the EEM effect is probably driven by a mechanism of disruption of encoding processes for neutral items when these are presented alongside emotional items. Specifically, this mechanism of disruption could be caused by the preferential capture of processing resources by emotional items, leaving little or no resources left to aid the encoding of neutral stimuli. This interpretation is consistent with results from the eyewitness memory literature suggesting that emotion-induced impairment of memory for irrelevant, peripheral information might be partly caused by competition for attentional resources (Christianson et al., 1991) and with evidence that the EEM is partly determined by differences in the allocation of attention between emotional and neutral stimuli (Christianson, 1992; Talmi et al., 2007; Maddox et al., 2012; Pottage & Schaefer, 2012).

A question that needs further consideration regards the specific nature of the encoding processes that were apparently disrupted in our results. An interpretation derived from the literature on the Dm effect (Paller & Wagner, 2002; Otten et al., 2007) could suggest that these processes involved a trial-by-trial attentional engagement aimed at an enhanced semantic processing of information at encoding. Applied to our study, this interpretation would mean that attentional resources necessary for this semantic processing would be allocated essentially to emotional items, thereby preventing a deep semantic processing of neutral items. This interpretation would fit well with literature suggesting that emotional items trigger a deeper level of semantic processing than neutral items (Barnard & Teasdale, 1991; Philippot et al., 2003; Schaefer et al., 2003), and with well-known effects indicating that enhanced semantic processing aids encoding (Craik & Lockhart, 1972). However, the temporal and spatial properties of our ERP effects do not fully support this hypothesis. Dm effects sensitive to differences in levels of semantic processing are typically seen in a time window starting at ~400 ms and often observed in fronto-central sites (Otten et al, 2001; 2007; Friedman et al., 2000). In our data, although a general Dm effect including frontal sites in the 400-800 time window was significant, it was not affected by our manipulation (no interaction involving Memory, List and

Emotion). Instead, the effect of a disruption of encoding for neutral information in mixed lists was observed in more centro-parietal sites, in different time windows (200-400 and 800-1500).

Rather than a process of trial-by-trial enhanced processing of semantic features, the morphology of our ERP effects suggests a two-step process leading to a temporally sustained processing of pictorial information in Working Memory (WM). The first step would consist of a "relevance detection" mechanism aimed at determining if a given stimulus is relevant for the ongoing task goals and, consequently, if additional resources need to be allocated to process this stimulus. The second step would involve a process of temporally sustained maintenance and manipulation of pictorial information in WM which could facilitate encoding. These two processes would be sequential and the second step would be a causal consequence of the first step: The relevance detection process would be a trigger for the implementation of the more resource intensive processes involved in the second step. This idea is not novel and the sequential combination of similar processes has been described in other contexts, such as the attention to affective pictures (Schupp et al., 2006) and in general models of WM and cognitive control (Botvinick et al., 2001; Kerns et al., 2004; Mushtaq et al., 2011). In the case of the EEM effect, our results suggest that these processes are disrupted for neutral information in mixed environments because they would tend to be preferentially mobilized by emotional items.

This interpretation is consistent with the morphology of the ERP effects that we observed in our study. First, the effects observed in the early time window overlap with latencies in which early Dm effects have previously been observed (Duarte et al., 2004; Mangels et al, 2001) and interpreted as early attentional processes aiding encoding. In our data, this effect conforms to the morphology of an early P3 effect, which is widely thought to be related to attentional processes (Polich, 2007), and which can often be observed in centro-parietal sites (Ferrari et al., 2010). A possible interpretation of the P3-like effect that we observed is that it could reflect focal engagement of attention on task-related items that need enhanced processing. In other words, this initial P3 could reflect a "call for resources" (Schupp et al., 2006), i.e. an initial step in a sequence of resource-demanding processes likely to involve WM and cognitive control processes. This explanation would fit well with usual interpretations of P3 effects (Polich, 2007; 2010; Olofsson et al., 2008), as well as with ERPs to realistic affective scenes observed in similar latencies (Schupp et al., 2006). Second, the effect that we observed in a late 800-1500 window overlaps with the latencies of late Dm effects previously reported in the literature (e.g. Caplan et al, 2009; Kim et al, 2009; Mangels et al., 2001, Otten & Rugg, 2001) and more generally with "slow waves" or "Late LPPs" which have often been reported on a similar 800-1500 time window (Ruchkin et al., 1988; Revonsuo & Laine, 1996; de Haan &Nelson, 1999; Leutgeb et al., 2009; Schienle et al., 2011) and can be observed in posterior sites (e.g. Ruchkin et al, 1988; Garcia-Larrea et al., 1998) .

Similar slow waves are usually thought to reflect a temporally sustained attentional engagement that can be linked to sustained maintenance and/or manipulation of information in WM (Olofsson et al., 2008; Ruchkin et al., 1988; Schupp et al., 2006). Therefore, in the current study, this effect could reflect the maintenance and manipulation of visual pictorial information in WM, leading to successful encoding. For instance, it could be possible that WM resources are recruited because participants are trying to create links between stimuli in order to facilitate encoding (Talmi & McGarry, 2012). For emotional stimuli in particular, participants could be trying to regulate their emotional reactions (Richards & Gross, 2000; Dillon et al., 2007), or engaging in self-referential processing (Conway & Dewhurst, 1995). Applied to the case of encoding intermixed emotional and neutral stimuli, the "relevance detection" step of the model described above could be highly influenced by the emotional content of the stimuli. Emotional stimuli are more likely to be considered as task-relevant because they provide clear signals that extra-ordinary resources need to be mobilized (Schaefer et al., 2006; Schaefer & Gray, 2007). The reasons for this link between emotional content and task relevance can be multiple. To speculate, the relevance of emotional stimuli could be simply determined by their evolutionary significance (Frijda, 1986; Ohman et al., 2001), or because they trigger bodily and motor responses that need to be self-regulated (Ochsner & Gross, 2005). In the case of an encoding task, emotional stimuli could also be appraised as relevant because they provide more opportunities to create links of relatedness with other emotional stimuli presented in the same list (Talmi & McGarry, 2012). The main implication of a potential link between emotional content and task relevance within the framework of the 2-steps model described above is that the engagement of encoding-related resources would be "switched on" preferentially to emotional and not neutral stimuli. This preferential allocation of resources to task-relevant stimuli could explain why both behavioural recall and Dm effects are dampened for neutral stimuli in mixed lists.

Although our data strongly suggests an explanation based on WM and cognitive control resources, a possible alternative explanation of our results could be that the effects of distinctiveness (mixed vs. pure contexts) on encoding would be due to trial-specific retrograde and/or anterograde impairment effects. In particular, it has been reported that an emotional item can cause a disruption of short-term consolidation of a neutral item preceding it (Strange et al., 2003). Although evidence for this effect is somewhat mixed (Angelini et al., 1994), reliable reports of emotion-induced retrograde amnesia of neutral items are available, and evidence suggests that this effect might be linked to the β-adrenergic system (Strange et al., 2003). Specifically, noradrenaline/norepinephrine increases linked to the perception of an emotional stimulus would both enhance encoding for this emotional stimulus and disrupt the consolidation of an item encoded a few seconds earlier. This mechanism could potentially explain our results: in the mixed condition, neutral items are obviously more vulnerable to instances of emotion-induced disruption of consolidation than in pure lists. In order to examine if such mechanisms were playing a role in our data, we tested if the recall of each item was influenced by whether the item just following it was emotional or neutral. However, we did not find any statistically significant differences in recall rate between neutral items followed by neutral or emotional items [M = .25, .25, SDs = .09, .07, respectively, $t(26) < 1$]. We do acknowledge that the trial procedure might not have had the precise timing features optimal to bring about the effect of emotion-induced retrograde amnesia.

Nonetheless, this result does not argue in favour of an alternative account based on short-term consolidation processes. Regardless of retrograde memory effects, it is also possible that our results might be due to effects of trial-specific anterograde impairments of memory for neutral items. Specifically, it could be possible that the encoding of a neutral item is impaired because of a *transient* depletion of processing resources caused by the previous occurrence of an emotional item in the previous trial (trial "n-1"). However, we did not find statistically reliable effects of the emotionality of trial n-1 on the recall performance for neutral items. In other words, recall for neutral items preceded by equally neutral items at encoding was not significantly different from the recall of neutral items preceded by emotional items [M = .24, .26, SDs = .09, .06, respectively, $t(26) < 1$]. This specific result suggests that the effects of distinctiveness on encoding of neutral items may be due to a temporally sustained mode of allocating processing resources to emotional and neutral items throughout each encoding list rather than transient effects on a trial-by-trial basis.

Two additional questions related to our data deserve further consideration: First, there is an apparent discrepancy between the ERP results and behavioural data in pure lists. Behavioural results for pure lists indicate a better recall for emotional compared to neutral stimuli, whereas Dm effects appear reliable in both. A possible explanation is that the large Dm effect for neutral items in pure lists reflects a higher level of cognitive effort needed to successfully encode neutral compared to emotional items in pure lists. Specifically, the emotional content of stimuli can be a powerful aid to encoding even when distinctiveness is cancelled in pure lists, as shown by studies reporting that the

EEM effect can be observed in pure lists (Mather & Nesmith, 2008; Monnier & Syssau, 2008; Brown & Schaefer, 2010; Majerus & D'Argembeau, 2011) . Neutral items obviously do not benefit from this aid, and are likely to require more elaborated strategies of encoding that require a greater level of attentional and cognitive control resources. A higher level of cognitive effort is known to increase brain activity (Gray et al., 2005), including ERP late positivities (Garcia-Larrea et al., 1998) and a high level of elaborative processing is known to increase Dm activity (Paller & Wagner, 2002, Otten et al, 2007; Caplan et al., 2009). Therefore, it is possible that a large Dm positivity was observed in the neutral-pure condition despite a modest recall performance simply because, for these items that were recalled, a high level of cognitive effort was employed. It is noteworthy that this level of high effort was unlikely to be engaged in mixed lists because the processing resources needed for this activity were probably allocated to emotionally negative items, as explained above. Second, the subsample analyses by levels of arousal do indicate that Dm effects for negative items are not a spurious effect of arousal above and beyond an effect of memory. However, they also show that, although the Dm effect is clearly significant for high arousal items, it appears non-significant for low arousal items. There are two potential explanations for this effect. First, it is possible that the absence of an effect for low arousal items is caused by a lack of statistical power due to the low size of the subsample (N=15) where these effects could be tested. Second, it might be caused by the fact that low arousal items are always facing a disadvantageous balance of processing resources: Both in mixed and pure lists, they are embedded together with high arousal items that are more likely to mobilize most of the attentional and WM resources necessary to aid encoding. Future research will be needed to explain further these questions.

The present findings can provide suggestions for future research. First, although there are strong indications that a competition for attentional resources between emotionally negative and neutral stimuli might be driving the effects reported in this paper, future research would be needed to fully ascertain this possibility. An interesting approach could involve combining the methodology of the current study, ERP methods and a paradigm of divided attention and/or a paradigm including measures of attentional cost similar to the behavioural paradigms used by Talmi et al. (2007) and Pottage and Schaefer (2012). Second, although our ERP results suggest that maintenance and manipulation of information in WM plays a significant role in EEM, future research will be needed to directly test this hypothesis with paradigms that manipulate the availability of WM capacity. Third, we used only negatively-valenced stimuli to operationalize emotional stimuli. Further research will be needed to verify if the current findings can be extended to positively-valenced stimuli. The potential of a differential effect of negative and positive emotions on memory is indeed a matter of debate (Kensinger & Schacter, 2008).

2.5.1 Conclusions

In summary, the results of this study show that ERPs reflecting the encoding of neutral stimuli in memory are cancelled when these are embedded in contexts that include emotional items. Taken together, these findings suggest that EEM effects can in part be driven by a disruption of encoding processes for neutral items in mixed lists (where emotionally negative and neutral items are intermixed), and that this phenomenon might be caused by an asymmetrical competition for attentional and working memory resources between emotional and neutral stimuli.

Chapter 3: Investigating the neural fate of neutral items and the role that individual differences play in the immediate emotional enhancement of memory

3.1 Chapter Overview

This work aims to replicate the previous findings surrounding the impact of distinctiveness on the immediate emotional enhancement of memory. In addition, this chapter explores the role that individual differences in working memory, emotion regulation and measures of personality can play in the EEM. This study finds that distinctiveness can influence the EEM in two different ways and these effects are the results of a two-step encoding process primarily involving the cognitive factors of attention and working memory.

3.1.1 Introduction

Emotional memories are known to have noticeably different characteristics in comparison to neutral memories (Schaefer, Pottage & Rickart, 2011), whereby emotional events have a mnemonic advantage over neutral events. Emotional items tend to be remembered in greater sensorial detail and recalled with an enhanced sense of confidence, compared to memories for neutral items (Schaefer & Philipot, 2005); this phenomenon has recently been referred to as the emotional enhancement of memory (EEM) and has been examined in cognitive psychology for many years (Talmi, Schimmack, Paterson & Moscovitch, 2007; Dolcos & Cabeza, 2002; Pottage and Schaefer, 2012; Schaefer & Philipot, 2005; Cahill and McGaugh, 1998; Kensinger & Schacter, 2008). EEM is thought to be important in the aetiology of some mental disorders therefore has implications in the field of clinical psychology (Lanius et al., 2003). Although EEM is well investigated psychological effect, little is known about the underlying cognitive factors responsible. McGaugh (2004) has attempted to explain the phenomenon in terms of amygdala-hippocampal interactions; whereby the increased arousal levels of emotional stimuli activates the amygdala, which in turn modulates the long-term encoding in the hippocampus (see LaBar & Cabeza, 2006 for review). Although these studies support a wealth of data in regards to the long-term enhancement of emotional material, they offer little support for the studies demonstrating immediate emotion enhancement of memory (Talmi & McGarry, 2012; Talmi, Anderson, Riggs, Caplan, Moscovitch, 2008; Talmi, Schimmack et al., 2007).

The behavioural literature has outlined several different cognitive-mediating factors that could influence the immediate emotional enhancement of memory. For example emotional items have been shown to utilise a deeper meaning based processing (Schaefer et al., 2003) with an enhanced level of semantic processing (Talmi & Moscovitch, 2004) and tend to be processed in a more self-referential manner (Conway & Pleydell-Pearce, 2000). Another suggested factor is the role that executive control plays over cognitive function, as effortful tasks have been shown to have an impact on memory at both encoding and retrieval (Dewhurst & Brandt, 2007). A widely accepted factor known to play a role in EEM is the increased attentional resources that emotional stimuli attract (Pottage & Schaefer, 2012; Talmi, Schimmack et al., 2007; Talmi et al., 2008; Kensinger & Schacter, 2008). It has been argued that this effect may be caused by the distinctiveness of emotional stimuli when they are intermixed with neutral stimuli (Dewhurst & Parry, 2000; Talmi, Luk, et al., 2007, Watts, Buratto, Brotherhood, Barnacle & Schaefer, 2014).

Experiments investigating the effects of distinctiveness and EEM employ a mixed versus pure list presentation design; where stimuli is presented either in mixed lists (which intermix emotional and neutral items) or in pure lists (homogenous blocks of only emotional or only neutral items). Schmidt (1991) was the first to empirically look at the concept of distinctiveness and formed an important distinction between what was coined ‘absolute’ distinctiveness and ‘relative’ distinctiveness. Schmidt (1991) proposed that ‘absolute distinctiveness was the result of incidental overlap between features of any items in what was named, the ‘active conceptual framework’. The ‘active conceptual framework’ is made up of neutral items that are usually stored in one’s long-term memory (before experimentation manipulation) such as people, buildings and cars. As such the emotional items have unique features not shared with typical items stored in the active conceptual framework, making them more distinctive. On the other hand ‘relative’ distinctiveness, Schmidt (1991) refers to as, the overlap that items have with the active conceptual framework items, maintained in working memory. Therefore in an experimental setting when emotional images (e.g. a robbery scene) are presented alongside neutral items, the emotional images are relatively distinct against the background of neutral items. Schmidt (1991) concluded that it is this relative distinctiveness not absolute distinctiveness, which enhances memory. This finding is supported by Dewhurst and Parry (2000), who found a strong enhanced memory effect for negative words over neutral words when presented in a mixed list; showing how it is the relative distinctiveness that is the most important factor. Likewise Schmidt and Saari (2007) found non-taboo emotional words to be remembered better than neutral words, again concluding that the non-taboo emotional words rely in item distinctiveness.

Recently Talmi, Luk et al., (2007) examined the effects of distinctiveness and emotionality using images and highlighted it is possible to change or manipulate the relative distinctiveness of an item by changing participants' active conceptual framework. For example, presenting items in a mixed list condition the items will have relative distinctiveness. However, in the pure list condition, the homogenous nature of the items means the relative distinctiveness advantage for emotional items is removed. Talmi, Luk et al. (2007) found when using this manipulation after immediate testing, memory for emotional, memory for emotional items relative to neutral items was enhanced in the mixed lists (which contained both negative and neutral images) only; i.e. when distinctiveness was allowed to play a role.

The current explanation as to what causes distinctiveness to have such a robust effect up EEM is explicitly linked to the role of attention. It is well-known that emotional items are processed preferentially because they can hold important motivational relevance (Eimer & Holmes, 2007; Ohman, Flykt & Esteves, 2001; Ohman & Mineka, 2001). This idea broadly supports the literature about eyewitness testimony, which posits emotional items in a given scene attract attentional resources, at the expense of those resources being used on neutral or less relevant objects, at the scene (Loftus, Loftus & Messo, 1987; Christianson, 1992). This account goes a way to explain how the role of distinctiveness impacts emotional items and the EEM, however the role that neutral information plays in EEM is far less well documented.

The study presented in Chapter 2 aimed to investigate the role that neutral items play in EEM and the electrophysiological correlates of the cognitive factor, distinctiveness, as a whole. Watts et al. (2014) found that recall performance for neutral items was lower in the mixed-list condition, compared to the pure-list condition. It was also found that the Dm effect for neutral items was cancelled in an early (200-400) time window and later (800-1500) time window, specifically at posterior sites. It is suggested that these results support the notion that preferential capture of emotional items in a mixed list presentation leave little or no attentional resources left to effectively encode the neutral items; in line with the eyewitness testimony literature, which suggests memory impairment for irrelevant peripheral information is due to the competition for attentional resources (Christianson & Loftus, 1987; Christianson, 1992). Therefore the main objective of this study was to replicate these novel findings, presented in both Chapter 2 and in the Watts et al. (2014) article and continue the empirical research into the electrophysiological correlates of EEM.

Using a replication of the paradigm outlined in Chapter 2 (see 2.1 Methods, Chapter 2) this study used recorded electrophysiological activity whilst employing a mixed versus pure list design, to investigate the role of distinctiveness in EEM and specifically, the fate of neutral information. This study also used the subsequent memory effect or Dm effect (Paller & Wagner, 2002) as a neural index of encoding, to explicitly examine the processes involved with emotional and neutral items at encoding, whilst manipulating the cognitive factor of distinctiveness. The Dm effect has been extensively used as a neural index of encoding (Paller, Kutas & Mayes, 1987; Mangels, Picton & Craik, 2001; Rugg, Otten & Henson, 2002; Duarte, Ranganath, Winward, Hayward & Knight, 2004; Otten, Quayle, Akram, Ditewig & Rugg, 2006) and many ERP studies have consistently reported a Dm effect as being characterised by a larger positivity for subsequently remembered items in comparison to subsequently forgotten items (Paller & Wagner, 2002). For more detail on the use of the Dm effect in ERP studies see Chapter 2 (2.1 Introduction, Chapter 2).

It is expected that the results will replicate the previous studies and support the hypothesis of a two-step process, leading to emotional items being temporally sustained in Working Memory (WM); with an early Dm effect reflecting an early P3-like effect, which is the result of engaging attention on task-related items that need enhancing (Schupp, Flaisch, Stockburger & Junghofer, 2006). This then causes the later Dm effect, which reflects the temporally sustained attentional engagement of sustained maintenance and or manipulation, of the emotional information in WM (Schupp et al., 2006; Olofsson, Nordin, Sequeira & Polich, 2008).

3.1.2 Individual Difference measures

In addition to these primary aims, the study also introduced four measures of individual differences to explore whether factors of personality can have an impact on recall performance of both emotional and neutral items and how they might interact with the known neural correlates of distinctiveness.

The study first looked at working memory capacity (WMC) and how this can affect both recall performance and the electrophysiological correlates of distinctiveness. Elward, Evans and Wilding (2012) strongly argue that measures of individual differences should be included in studies, which aim to investigate how and or why people exert control over what they remember. Working memory has been an intense subject of investigation for many years (Baddeley & Hitch, 1974; Baddeley, 2000; Baddeley, 2003) and it is an important facet to many aspects of cognition, with research encompassing various factors such as attention (Oberauer, 2002; Bleckley, Durso, Crutchfield, Engle & Khanna, 2003) and general intelligence (Conway, Kane & Engle, 2003); as well as investigations into the neural regions involved in working memory capacity (Kane & Engle, 2002). Research into WM has also shown a crucial link between the amygdala (classically viewed as a brain structure involved with emotion) and higher cognitive function, involving working memory (Schaefer et al., 2006). Given the conclusions of the previous experiment (Watts et al., 2014) surrounded the maintenance and manipulation of pictorial stimuli in WM and given the importance of WM as a whole, it was decided the role of WM in this study warranted further investigation.

To measure WMC, an automated version of the Operation Span (OSPAN) was administered to each participant (Unsworth, Heitz, Schrock & Engle, 2005). The OSPAN is a widely used method to measure WMC (Tuner & Engle, 1989; Bleckley et al., 2003; Elward & Wilding, 2010; Elward et al., 2012) and has shown to correlate with other measures of WMC such as Raven Advanced Progressive Matrices (Unsworth & Engle, 2005). Work on the ERP index of recollection (the left-parietal ERP old/new effect) has shown a larger WMC correlates with a larger ERP index of recollection, suggesting WMC can act as an index for the availability of resources exerting cognitive control at memory retrieval (Elward et al., 2010). Work on WMC and visual attention has also shown that high WMC individuals can flexibly allocate attention, whereas low WMC individuals tend to allocate attention as a spotlight (Bleckley et al., 2003). Taking these findings into consideration, it was expected that participant who have a high WMC will be able to allocate attention more flexibly (Bleckley et al., 2003) and firstly, during the initial step of detecting the stimulus, using their additional WMC resources to process both negative and neutral stimuli equally. Then in the second phase, high WMC participants would be able to sustain and maintain both the negative and neutral stimuli in WM, which would facilitate the encoding. It was expected that individuals with low WMC would not have additional resources available in the initial step to allocate attention to both negative and neutral information, therefore only the negative stimuli would be attended too, as emotional stimuli are considered more task-relevant (Schaefer et al., 2006; Schaefer & Gray, 2007). Therefore only negative stimuli would subsequently be maintained in WM to facilitate encoding. If WM was playing a role at encoding it was expected this would be reflected in the ERP data; with high WMC individuals having an equal Dm effects for both negative and neutral items, whereas low WMC participants would show a reduced Dm for neutral items.

The second measure of individual difference examined was emotion regulation. Emotion regulation is the study of how people influence which emotions they have, when they have them and how individuals experience and express emotions (Gross, 1998). An emerging field of research into emotion regulation lead by Gross and colleagues has found both affective consequences and cognitive consequences to emotion regulation (Richards & Gross, 2000). Two main types of emotion regulation strategies have been outlined by the literature (Gross, 2002; Gross & John, 2003; Gross, Richards & John, 2006): the first is reappraisal, an early stage of the emotion-generative process that changes the way an emotional situation is construed, to decrease its emotional impact; the second is suppression, a later stage in the emotion-generative process that involves inhibiting the outward expression of an emotional experience and inner feelings. Reappraisal is often found to be a more successful emotion regulation technique than suppression (Gross, 2002), however suppression is thought to have the greater cognitive consequences for memory (Richards & Gross, 2000; Gross, 2002; Gross & John, 2003; Oschner & Gross, 2005; Richards & Gross, 2006; Shimmack & Hartmann, 1997; Egloff, Schmukle, Burns & Schwerdtfeger, 2006). Where reappraisal decreases the emotional experience and has no impact on memory, suppression fails to decrease the emotional experience and can actually impair memory. This study used the Emotion Regulation Questionnaire (ERQ) (Gross & John, 2003), which measures a respondents likelihood of regulating their emotions in both reappraisal and suppression methods. The two facets are measured individually in the questionnaire so they can be treated as separate facets at analysis. It was expected that reappraisal would have no significant effect upon recall and would reflect no significant correlation with the Dm effect in the ERP measures, irrespective of whether participants measure high or low for the reappraisal technique of emotion regulation. However, participants who scored high for suppression (i.e. more likely to employ suppression as an emotion regulation technique) were expected to significantly recall less negative (emotional) items and the suppression scores were expected to significantly correlate with the negative Dm effect in the ERP measures.

The third measure of individual difference was the implementation of the Big Five Inventory for each participant to assess the impact personality dimensions can have upon memory recall. The Big Five has an extensive history, starting with the very first attempts to lexically extract personality descriptions from everyday language (Allport & Odbert, 1936), through the debate over states and traits, right through to the Big Five dimensions defined by Goldberg (Goldberg, 1990; Goldberg, 1993). Whereas, the relatively new field of personality neuroscience is just emerging; which aims to study psychologically relevant individual differences through neuroscientific methods (DeYoung & Gray, 2009). The five traits now synonymously known as the Big Five refer to Extraversion, Neuroticism, Agreeableness, Conscientiousness and Openness/Intellect (John, Naumann & Soto, 2008); the traits have been collated into a 44-point questionnaire called the Big Five Inventory (John et al., 2008), which measures the dimensions of the Big Five based on Goldberg (1993), which was administered to each participant in the study. Komarraju, Karau, Schmeck and Avidic (2011) define the traits as follows: Extraversion usually refers to a higher level of sociability, displayed through assertiveness and talkativeness. Neuroticism refers to the degree of emotional stability, anxiety and impulse control, one can exert. Agreeableness usually reflects being helpful and cooperative towards others and the ability to be sympathetic. Conscientiousness is reflected in a disciplined nature, being organised and achievement-orientated. Openness/Intellect is exemplified by a strong intellectual curiosity and a preference for variety and novelty.

Although the Big Five Inventory has been used extensively in the research of personality and these traits, there is little literature surrounding its influence on cognition; specifically emotion and memory. The field of personality neuroscience is gaining influence in this area and has conducted research into this area of personality measures and cognition. Investigations from DeYoung et al. (2010) found that Extraversion covaried with the volume of medial orbitofrontal cortex, a region in the brain involved with processing reward information. This supports evidence that suggests Extraversion traits such as assertiveness and talkativeness represent approach behaviours associated with seeking out potential rewards (DeYoung, 2010). EEG research into Extraversion has often surrounded its links with cortical arousal. The results however have been generally inconclusive, with sometimes positive associations and sometimes negative associations being found between Extraversion and cortical arousal (Matthews & Gilliland, 1999). Canli et al. (2001) conducted an fMRI study and found Extraversion was correlated with brain activity to positive stimuli whereas Neuroticism was correlated with brain reactivity to negative stimuli. Neuroimaging studies have linked Neuroticism with many brain structures associated with reactions to threat and punishment, such as the amygdala and anterior cingulate (DeYoung et al., 2010). Another factor often linked with Neuroticism is higher levels of stress, which DeYoung (2010) argues, means individuals are less able to mobilise resources, particularly when they are in stressful situations. Agreeableness itself has not often been the subject of investigation by neuroscience, however one study did find brain volume in regions associated with social information processing (superior temporal sulcus and fusiform gyrus) to be associated with Agreeableness (DeYoung, 2010). Conscientiousness is known to predict academic achievement (Komarraju et al., 2011) but it was also found to be associated with a greater volume in the middle frontal gyrus of the lateral prefrontal cortex (DeYoung et al., 2010), a region DeYoung (2010) argues is involved in maintain goal-relevant information in working memory. Finally, Openness/Intellect is known to consistently be positively associated with cognitive abilities such as academic achievement (Komarruju, Karau & Schmeck, 2009), intelligence and working memory capacity (DeYoung, Shamosh, Green, Braver & Gray, 2009; DeYoung, Peterson & Higgins, 2005). Furthermore it was shown that Intellect but not Openness was responsible for the association on a difficult working memory task (DeYoung et al., 2009).

As little work has specifically investigated the role that personality measures of the Big Five Inventory have upon emotional memories, this study serves to explore these interactions rather than address specific hypothesis. Despite this, from the literature reviewed above there were some general expectations; it was expected that Openness/Intellect would correlate most strongly with both recall performance, based on the association with intelligence and working memory (DeYoung et al., 2009). It was expected that Conscientiousness could also play a role in memory recall (although to a lesser extent than Openness/Intellect) for the same reason that it has been associated with goal-relevant information in working memory (DeYoung, 2010) and academic performance (Komarraju et al, 2011). It is also thought that Extraversion and Neuroticism could play a role; Extraversion as it has been associated with crucial brain regions (amygdala) which are known to have an impact upon higher cognitive functions, such as working memory (Schaefer et al., 2006); and Neuroticism as it has been shown to predict greater brain activity in fMRI studies when associated with negative stimuli (Canli et al., 2001). Agreeableness was not expected to play a great role, although its associations with empathy a facet to Agreeableness (DeYoung, 2010) means it could have an impact in the present study, which uses some highly emotive stimulus.

The final individual difference area of investigation is the Behavioural Inhibition System and the Behavioural Approach System (BIS and BAS; Carver & White, 1994). The BIS BAS systems represent two theoretical dimensions of temperament: anxiety and impulsivity (Pickering & Gray, 1999). Originally it was proposed that the BIS system reflected sensitivity to Anxiety and was activated by novel stimuli and by conditioned stimuli signalling punishment; whereas the BAS system reflected Impulsivity and was activated by conditioned stimuli signalling reward or relief from punishment (Pickering et al., 1999). However, more recently it was suggested that the BIS sensitivity to Anxiety was difficult to distinguish from Neuroticism and likewise the BAS sensitivity to Impulsivity was difficult to separate from Extraversion; indicating that the BIS and BAS would be better referred to as measures of Neuroticism and Extraversion, respectively (DeYoung & Gray 2009; Gray et al., 2005). It is widely accepted that BIS reflects sensitivity to cues of threat, which can induce behavioural inhibition and withdrawal; and BAS reflects sensitivity to reward, which induces behavioural approach (Gray et al., 2005).

Extraversion and Neuroticism are known to be susceptible to pleasant and unpleasant emotional states (Gross, Sutton & Ketelaar, 1998) however, the impact of affective dimensions of personality upon cognition is an emerging field, with little research done on personality and its effects on emotion and memory. A common theory to explain the links between personality and cognition and often applied to Extraversion, is the arousal theory (DeYoung, 2010; Gray et al., 2005). This posits Extraversion is a function of levels of cortical arousal and Extraverts have lower arousal levels than Introverts do (DeYoung, 2010; DeYoung et al., 2009; Gray et al., 2005). This assumption fits with the reward sensitivity model; whereby Extraversion is associated with dopamine (linked to reward and positive affect) and Neuroticism is associated with norepinephrine (linked to anxiety and wakefulness) (DeYoung, 2010; Gray et al., 2005). EEG studies designed to test the arousal hypothesis have often been contradictory (DeYoung, 2010), however links have been drawn between the role of arousal and dopamine on cognitive performance (DeYoung et al., 2009; Gray et al., 2005). Moderate arousal levels have been linked with better performance in difficult cognitive tasks, however high and low levels of arousal are associated with reduced performance (Humphreys & Revlee, 1984). Although Extraversion itself is not predictive of working memory performance, it has been suggested that the higher dopamine levels could relate to the ways individuals are motivated to perform difficult cognitive tasks (DeYoung et al., 2009). Research into personality's affective dimensions and cognition has generally centred on the higher cognitive function of working memory (Gray & Braver, 2002; Gray et al., 2005; Lieberman, 2000; Lieberman & Rosenthal, 2001). The results are generally discussed in term of the processing efficiency hypothesis, whereby Extraverts (high BAS scores) have a better working memory in complex cognitive tasks, as they are better suited to multitasking and more efficient (not due to overall storage capacity, Lieberman et al., 2001). Whereas Introverts (low BAS scores) are slower at comparing the contents of working memory and less able to multitask (Lieberman, 2000; Lieberman et al., 2001). Individuals who score high on the BIS scale and are more anxious, generally need to exert a greater mental effort to achieve the same level of performance as low BIS individuals because they work less efficiently but can compensate by working harder. However, when the cognitive load it greater and the demand increases, the performance of anxious individuals become impaired as they are no longer able to compensate (Gray et al., 2002; Gray et al., 2005). This overall suggests that Extroverts would perform better in high arousal tasks, whereas Introverts would perform better in low arousal tasks (Gray et al., 2005). This study implemented the BIS/BAS scales (as developed by Carver & White, 1994) to measure each participants' sensitivity to the two underlying traits of Extraversion and Neuroticism.

Similarly to the Big Five Inventory, little research has been done to explicitly address how BIS/BAS measures influence emotional memory formation, therefore this study seeks to explore these interactions rather than test specific hypothesis. Based on the literature reviewed above however there were some general expectations. Individuals who score high on the BAS scale (deemed extroverts) have been shown to have a more efficient working memory capacity (Lieberman et al., 2001). The mixed-neutral condition of this study requires the greatest mental effort to encode the information as the items are competing for processing resources with mixed-negative items. Hence, given that extrovert individuals are better at multitasking and have an efficient working memory system, it is expected they will have higher recall rates in the mixed-neutral condition as they are able to more efficiently compare the contents of working memory and process the mixed-neutral information, compared to introvert individuals.

3.1.3 Aims

- The Primary experimental aim is to replicate the findings of Chapter 2 and confirm the role distinctiveness plays as cognitive mediating factor in immediate EEM.
- We expect to observe a significant interaction between the recall rates of the mixed-list condition and the pure-list condition; driven primarily by a reduction in mixed-neutral recall.
- We expect to find a reduction in the Dm effect for mixed-neutral items; specifically in an early 200-400ms time window and a later sustained reduction at ~800ms.
- Additionally we are investigating the impact of four personality measures: working memory performance, Emotion Regulation, The Big Five personality traits and the BIS/BAS scales, to see how they affect recall performance and the known ERP correlates of distinctiveness.

3.2 Methods

3.2.1 Participants

Forty-four healthy right-handed adults (31 females, mean age of 20.59 years, SD 3.73 years) from Durham University and the surrounding area, with no history of psychiatric or neurological conditions, took part in the study in exchange for course credits or were remunerated for their time (£15). All participants gave informed consent and the study was approved by the local ethics committee. In addition, due to the negative nature of the stimuli used any participants deemed vulnerable were excluded from taking part in the study. These participants were defined as people who scored above 21 on the Beck's Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961; see appendix A); and those who scored above 50 on State Trait Anxiety Inventory (Speilberger, Gorsuch & Lushene, 1970; see appendix B).

It has been shown that replication studies requite additional statistical power than the original study (Button et al., 2013), therefore given the replication nature of this study we employed more stringent exclusion criteria and wanted to make sure only participants that displayed a normal Dm effect were retained in the sample. This was necessary given that our hypotheses are about variations in Dm activity caused by emotionally negative and neutral factors, thus we needed to be certain that participants were displaying a normal Dm effect. As such, we looked carefully into individual Dm activity of every participant and found that six participants were exhibiting abnormal Dm activity. One participant had a Dm score in the pure-neutral condition that was over 3 SDs away from the mean, therefore was excluded from the final sample. An additional 5 participants displayed an inverted Dm scores across 1 or more of the key conditions. Analysis of these 5 participants' data confirmed there to be no significant effect of Memory in any of the key time windows (*ps* = .391, *ps* = .307, *ps* = .443, respectively); with forgotten items being more positive going than remembered items across the mixed-negative , pure-negative and pure-neutral conditions. This is in contrast to a random subset of the data with the same sample size, which does show a main effect of Memory across the two later time windows (*ps* = .053, *ps* = .002) and no inverted Dm effects across any conditions. Based on these results and the hypothesis of this replication study, it was decided to exclude the 5 participants showing inverted Dm results from the final sample. A further three participants did not have enough artifact free trials in at least one of the relevant conditions and one participants were excluded due to a corrupted data file of the ERP recording. This left a final sample of 34 participants (25 females, mean age of 19.53 years, SD 1.46 years).

3.2.2 Stimuli and Design

Participants were first required to complete the tasks and questionnaires to measure the aspects of individual difference (see 3.2.5 Controlling for individual differences, Chapter 3), including: a computerised version of the Automated Operation Span (Unsworth et al., 2005); the Emotional Regulation Questionnaire (Gross & John, 2003); the Big Five Inventory (John et al., 2008); and the BIS BAS scale (Carver & White, 1994).

The stimuli used were realistic colour images showing emotionally negative or neutral scenes, obtained from the International Affective Picture System (IAPS) (Bradley & Lang, 1994; Lang, Bradley & Cuthbert, 2005). Similar to previous studies (Yamasaki, LaBar & McCarthy 2002; Dolcos, LaBar & Cabeza, 2004), images were added to the IAPS data set from Google Image™ to ensure that the emotional negative and neutral images were balanced for key non-emotional dimensions (e.g. presence of humans, animals and objects; see appendix G). A total of 480 images were shown to the participants across all picture sets: 312 IAPS images and 168 from Google Images ™. Images were all resized to 455 x 342 pixel format and displayed centrally at 1024 x 768 pixels, on a 40cm x 30cm Samsung SyncMaster computer screen (TCO'03 Displays, MagicBright).

A sample of British students similar to the sample used in this study, previously rated all the images used in this study for valence and arousal (Schaefer et al., 2011; Pottage & Schaefer, 2012) using a 5-point version of the Self-Assessment Manikin (SAM): whereby Valence was rated as 1 = negative, 5 = positive; Arousal was rated as 1 = low, 5 = high arousal (Bradley & Lang, 1994). Using these ratings, the images were then divided into subsets of emotionally negative and neutral images: 240 emotionally negative images (mean valence = 1.94, SD = 0.38; mean arousal = 3.28, SD = 0.51) and 240 neutral images (mean valence = 3.12, SD = 0.98; mean arousal = 1.84, SD = 0.39). Analysis revealed that the image subsets were significantly different from each other for both valence and arousal ($p< 0.001$). The emotionally negative picture set, was further divided into high and low arousal using a median split, in order to perform complimentary arousal analysis. Analysis also showed a significant difference between the mean arousal scores of the high and low arousal image subsets ($p<0.001$): with a high arousal, mean arousal score = 3.69, SD = 0.34; low arousal, mean arousal score = 1.68, SD = 0.32.

The same methods were followed as in the first experiment (see 2.2.1 methods, Chapter 2), whereby the images were divided into 10 mixed and 10 pure lists, each containing 24 images. Five of the pure lists contained only neutral images and the remaining five pure lists contained only negative images. The mixed lists contained an equal mix of neutral and negative images, intermixed together. Both the pure and the mixed lists contained an equal amount of high and low arousal images and all lists were balanced for key non-emotional features, such as presence of humans, animals and objects. Half of the participants were presented with mixed lists first, followed by the pure lists and vice versa for the other half of the participants. During the pure list presentation, all the negative pure lists were presented one after each other and all the neutral lists were presented one after each other; that is to say, the pure lists were grouped and presented separately according to valence. In addition, the order of negative or neutral lists within the pure list condition (i.e. whether participants saw the negative pure lists first and the neutral pure lists second or vice versa) was counter balanced across participants and the order of both the lists presented and the pictures within each list, were also randomised. Finally, picture contents were alternated between the mixed and pure lists (i.e. the pictures used in the mixed lists for half the participants, were then used in the pure lists for the remaining participants).

3.2.3 Procedure

Prior to the participants completing the recall aspect of the experiment, all participants first filled out three questionnaires: Big Five Inventory (John, et al., 2008); Emotion Regulation Questionnaire (Gross & John, 2003); BIS/BAS scale (Carver & White, 1994). Participants also completed a computerised version of the Automated Operation Span (OSPAN) (Unsworth et al., 2005), which was run using E-Prime 2.0 (Psychology Software Tolls, Pittsburgh, PA). These questionnaires and tasks provided a measure of some aspects of individual differences, which were incorporated into the analysis (see 3.2.5, Chapter 3).

As this study sought to replicate the results observed in Chapter 2, the rest of the experimental procedure was the same as the first experiment (refer to 2.3.3 Procedure, Chapter 2). See Figure 3.1 for a schematic representation of the trial procedure for this experiment.

Similar to experiment one, based on the evidence from previous studies we used a liberal criterion, as this increase the amount of accurate information retrieved during memory tests, so as to maximise recall in our study (Pottage & Schaefer, 2012; Wright, Gabbert, Memon & London,2008).

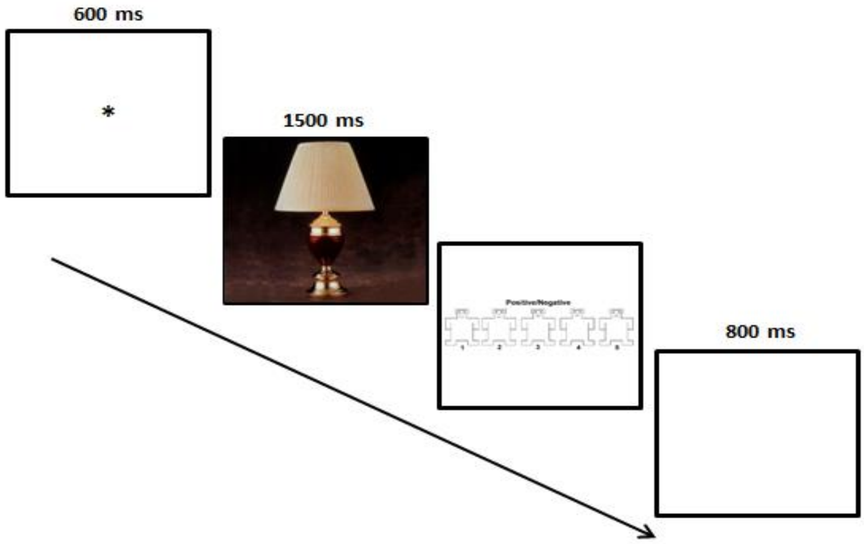

Figure 3.1: Schematic representation of the experimental trial procedure.

3.2.4 Memory Coding

Participants' free recall descriptions of each remembered image were recoded independently by two coders, following methods established by previous research (Bradley, Greenwald, Petry & Lang, 1992; Talmi, Luk et al., 2007; Pottage & Schaefer, 2012). Similar to previous work (Pottage & Schaefer, 2012; Watts et al., 2014), to prevent the probability of false positives (false memories being encoded as true memories), only descriptions that could be both identified as the image and differentiated from other images in the block, were classified as true memories. Any descriptions that were deemed as too vague to allow concrete identification or were difficult to differentiate from other images within the block were discounted as false memories. As with previous studies, the agreement between coders was high (96%) and any disagreements that did occur were resolved by taking a conservative interpretation of the approach outlined above.

3.2.5 Controlling for individual differences

Four different tasks were used to measure dimensions of individual difference, to assess if these personality dimensions could have an effect upon recall performance and ERP encoding waveforms.

OSPAN – All participants first completed an automated opsan task (Unsworth et al., 2005), which is a widely employed measure of working memory capacity (WMC) (Turner & Engle, 1989; Elward & Wilding, 2010; Elward, et al., 2013). The task involved solving a series of mathematical problems, whilst remembering a string of letters and all instructions were presented to the participant on the screen. For each trial, participants first saw a mathematical question (e.g. (2 x 3) + 2) and were instructed to make a key press when they had a solution to the problem. A possible solution to the problem was then displayed on the screen with a true or false response option; whereby participants were required to respond if the solution presented was true or false, to solve the mathematical problem. After the response, the screen then presented a single letter, which participants were instructed to remember for a subsequent recall test. The number of sequences of equations and letters presented (set size) before participants were cued to recall the letters, varied between three and seven. In total, three sequences of each set size were presented to the participants (total 75 maths problems). The percentage of correct mathematical solutions was displayed on the screen and participants were instructed to try and maintain this value at 85% or above. The OSPAN score was calculated as the sum of the number of remembered letters, recalled in perfectly recalled sets. For example, recalling all three sequences with two letters and two sequences with three letters would equal a score of 12 (= 2 + 2 + 2 + 3 + 3). The OSPAN scores of participants were used as a measure of WMC and were included in both a mixed analysis of variance (ANOVA) to assess if WMC had an impact upon recall performance, as well in correlational analysis with ERP difference waves (Dm effect, Paller & Wagner, 2002). Using a correlational approach to measure the impact of personality measures is a widely used method (Richards & Gross, 2000; Canli et al., 2001; Gray et al., 2005; Schaefer et al., 2006; DeYoung et al., 2009; Komarraju, Karau, Schmeck & Avdic, 2011); therefore the analysis of all the individual difference measures and ERP data have adopted this analysis technique, whereby the scores are correlated with difference waves (Walker et al., 2011) of the four key conditions (mixed-negative, mixed-neutral, pure-negative and pure-neutral), across anterior and posterior sites, in the three main time windows (200-400, 400-800, 800-1500).

Emotional Regulation- All participants completed the Emotional Regulation Questionnaire (ERQ, Gross & John, 2003), in order to examine whether emotional regulation has an impact upon cognitive process (Richards & Gross, 2000; Schimmack & Hartmann, 1997; Gray, 2001; Oschner & Gross, 2005) and specifically the memory encoding as presented in this study. The ERQ was administered to every participant and presented a 10-item scale, which was designed to measure the respondents' tendency to regulate their emotions, in one of two ways: by Cognitive Reappraisal and by Expressive Suppression. Participants answered each of the 10 questions on a 7-point Likert-type scale, ranging from 1 (strongly disagree) through to 7 (strongly agree). The scoring was kept continuous and the scores for each facet (Reappraisal and Suppression) were kept separate. The Reappraisal and Suppression scores were subject to separate median splits, following similar procedures to those outlined in the literature (Schimmack et al., 1997), to assign subjects to either being high-reappraisers or low-reappraisers and to either being high-suppressors or low-suppressors (see appendix D). Following methods previously outlined in the emotional regulation literature

(Schimmack et al., 1997; Richards & Gross, 2000; Bloise & Johnson, 2007), ANOVAS were computed to asses if the emotion regulation strategy had an effect on memory performance. One ANOVA was computed using the high and low groups of Reappraisal scores and a second ANOVA computed using the high and low groups of Suppression scores. In addition, the scores were also used in correlational analysis with ERP difference scores for each of the key conditions (see 3.2.5 Methods, Chapter 3).

The Big Five Inventory – Each participant completed a 44-Item inventory, which measures dimension of the Big Five (John, Naumann & Soto, 2008) in order to examine if any of the Big Five traits had an association with recall performance. Participants were instructed to answer each of the 44 statements using a 5-point Likert-type scale, from 1 (strongly agree) to 5 (strongly disagree). The scores were calculated separately for each of the five dimensions (Extraversion, Agreeableness, Openness, Neuroticism and Conscientiousness) and reverse scored where appropriate. The scores for each facet were correlated with recall performance across the four main conditions (mixed-negative, mixed-neutral, pure-negative and pure-neutral) and with ERP difference waves, as explained above.

Behavioural Inhibition System and Behavioural Activation System (BIS BAS) - Each participant completed the BIS/BAS scale (Carver & White, 1994) to assess if there is a relationship between these two underlying motivational systems and memory encoding, in this study. The BIS/BAS scale consisted of 24-items, which participants had to respond to using a 4-point Likert scale; from 1 (very true for me) to 4 (very false for me). The scores were marked accordingly, in two ways: 1) to create global BIS and BAS scores, where all items responding to BAS were summed together; 2) to create 4 sub-factors, where BAS scores were divided into BAS-Drive, BAS-fun seeking and BAS-Reward Responsiveness in addition to the BIS score. Similarly to the Big Five procedure, the scores were correlated with recall performance in the four key conditions (separate analyses were conducted for global scores and sub-factor scores), in addition to these scores being correlated to ERP difference waves.

3.2 6 Electrophysiological data recording and processing

Scalp electrophysiological activity (EEG) was recorded from a 64-channel cap (Waveguard, ANT Inc., Enschede, Netherlands) at a rate of 512 Hz (DC-138 Hz bandwidth) and an impedance < 20 kS. EEG data was recorded using an average reference and digitally converted to a linked mastoids reference. EEG data was analysed using the ERP module of BESA 5.3 (MEGIS software GmbH, Grafelfing, Germany). All data were filtered offline (0.03-30 Hz), corrected for eye movements (Berg and Scherg, 1994), segmented into epochs between 100 ms before and 1500 ms after stimulus onset and baseline corrected. For each channel, we rejected epochs that had a difference between the maximum and minimum voltage amplitudes exceeding 120 µV or a maximum difference between two adjacent voltage points above 75 µV (after eye-movement artifact correction).

ERP waveforms were created by averaging EEG data for Remembered trials (items that were successfully recalled) and Forgotten trials (items that were not recalled) separately for the Mixed list condition and the Pure List condition and for neutral or negative items, resulting in eight trial types: Mixed-Negative-Remembered, Mixed-Negative-Forgotten, Mixed-Neutral- Remembered, Mixed-Neutral-Forgotten, Pure-Negative-Remembered, Pure-Negative-Forgotten, Pure-Neutral-Remembered, Pure-Neutral-Forgotten. Participants, who contributed fewer than 12 artifact-free trials for at least one of these conditions, were excluded from the analysis (see Participants section). This criterion is consistent with many previous ERP studies on memory processes (Watts et al., 2014; Azimian-Faridani and Wilding, 2006; Kim, Vallesl, Picton & Tulving, 2009; Gruber and Otten, 2010; Galli, Wolpe & Otten, 2011; Padovani, Koenig, Eckstein & Perrig, 2013). The mean number of artifact-free trials per condition was: 44.08, 68.71, 26.94, 86.08, 39.53, 71.62, 34.62 and 77.53, respectively.

3.2.7 ERP data analysis

3.2.8 Selection of time windows and scalp locations

Based on a careful visual inspection of the data and to aid the replication aims of this study, mean amplitudes were extracted from the same three main time windows: 200-400, 400-800 and 800-1500ms (see 2.3.6 ERP data analysis, Chapter 2). These time windows allow this study to both, investigate and replicate the previous findings and to specifically target three key ERP effects, outlined in the literature (see 2.1.1 Introduction, Chapter 2). To briefly summarise, an early time window (200-400) covers the early Dm effects observed in the literature and more specifically, it targets the temporal regions usually found with ERP's associated to emotional images (Duarte et al., 2004; Mangels et al., 2001; Walker et al., 2011; Olofsson et al., 2008). The middle (400-800) time window covers Dm effects starting at ~400ms outlined previously in the literature (Friedman & Trott, 2000; Dolcos & Cabeza, 2002) as well as targeting the late positive potential (LPP) associated with ERP's to affective images (Codispoti, De Cesarel & Ferrari, 2012). The final late (800-1500) time window corresponds with sustained slow waves (often called the 'late LPP') the literature has outlines as being observed in an 800-1500 time window (Leutgeb, Schafer, Schienle, 2009; Schienle, Kochel & Leutgeb, 2011).

Scalp regions were selected based on the findings of Watts et al., (2014) and the previous research outlined in the introduction. Overall resulting in six scalp regions being selected, encompassing anterior and posterior regions, spanning across right, midline and left sites: left-anterior (F7, F5, F3, FT7, FC5, FC3), midline-anterior (F1, Fz, F2, FC1, FCz, FC2), right-anterior (F8, F6, F4, FT8, FC6, FC4); left-posterior (P7, P5, P3, TP7, CP5, CP3), midline-posterior (P1, P2, Pz, CP1, CP2, CPz) and right-posterior (P8, P6, P4, TP8, CP6, CP4). The data was averaged for single electrodes inside each ROI (Watts, et al., 2014; Schaefer et al., 2011; Walker et al., 2011; Curran, DeBuse, Woroch & Hirshman., 2006), in order to address familywise error in dense arrays of electrodes (Oken & Chiappa, 1986).

3.2.9 Statistical analysis

A repeated measures ANOVA was computed on the mean amplitude data from each of the time windows (200-400, 400-800, 800-1500) using the following factors: Memory (Remembered vs Forgotten items), Emotion (Negative vs Neutral items), List (Mixed vs List types), A-P (Anterior vs Posterior electrode sites) and Laterality (Left, Midline or Right electrode sites). Considering the replication nature of this study and its hypothesis, effects involving the factor of Memory were preferentially targeted and it was expected that the results would replicate the previous experiment (Watts et al., 2014), whereby there would be significant interactions involving the factors of Memory, Emotion, List and A-P. In addition, any significant effects involving the factor of Memory were followed up with subsidiary analysis, down to the level of Remembered vs Forgotten pairwise comparisons. For all analyses, partial eta-squares were reported to provide estimates of effect-size and Greenhouse-Geisser corrections were used, with corrected p values reported where relevant.

Statistical correlational analyses were also computed on the scores of individual difference (see 3.2.5 Controlling for individual differences, Chapter 3).

3.2.10 Controlling for arousal

Analysis were also performed using the arousal levels of the images, to ensure that any effects observed with negative items were not the result of confounds between the Dm effect and the effect of arousal on ERP amplitude. It is well established in the literature that arousal is linked with an overall increased positivity in ERP's (Schupp et al., 2000; Codispoti, Ferrari & Bradley, 2007); therefore if the results show an overall positivity for Remembered negative items compared to Forgotten negative items, it could be argued this is merely reflecting the fact that Remembered items are more arousing than subsequently forgotten items. To address this possibility, as in previous research (Watts et al., 2014), the Dm effect was recalculated within sub-groups of the negative images: low-arousal mixed remembered, low-arousal mixed forgotten, high-arousal mixed remembered, high-arousal mixed forgotten, low-arousal pure remembered, low-arousal pure forgotten, high-arousal pure remembered, high-arousal pure forgotten. These groups were selected by performing a median split on arousal level of all negative images (see 3.2.2 Methods, Chapter 3). If the Dm effect observed within negative images is mainly due to confounds within arousal levels, then it is expected that the Dm effect on low-arousal and high-arousal sub-groups would be reduced and or cancelled. These analyses were performed on a sub-sample of 25 participants who had enough artifact-free trials for both the high-arousal and low-arousal conditions. The mean number of artifact-free trials in the condition was: 20.08, 36.52, 27.04, 29.88, 20.56, 37.00, 25.16 and 32.16, respectively.

3.3 Results

3.3.1 Behavioural Results

3.3.1.1 Recall

An Emotion x List within-subjects ANOVA was performed on the recall rates and revealed a significant main effect of Emotion [$F(1, 33) = 60.73$, $p < .001$, $\eta p^2 = .65$] showing, as expected emotional images were better recalled than neutral images. There was also a significant interaction between Emotion and List [$F(1, 33) = 67.02$, $p < .001$, $\eta p^2 = .67$]. Breaking down this interaction, it was found that there was a significant effect of Emotion in both the mixed [$F(1, 33) = 115.31$, $p < .001$, $\eta p^2 = .77$] and the pure lists [F 1, 33) = 6. 73, $p < .01$, $\eta p^2 = .17$], however the significance level and effect size were both smaller in the pure list condition. There was a significant effect of List in the neutral condition [$F(1, 33) = 24.18$, $p < .001$, $\eta p^2 = .43$], which is consistent with previous results and the hypothesis (as shown in Figure 3.2), showing a reduction in the amount of neutral items recalled in the mixed list compared to the pure list (mean proportion recalled in, mixed list = .24; pure list = .31). There was also a significant effect of List in the negative condition [$F(1, 33) = 16.89$ $p < .001$, $\eta p^2 = .39$], which was not shown in the previous study. This is however still consistent with the hypothesis about mixed lists, showing the negative items are recalled better in the mixed list (mean proportion recalled = .39) compared to the pure list condition (mean proportion recalled = .34).

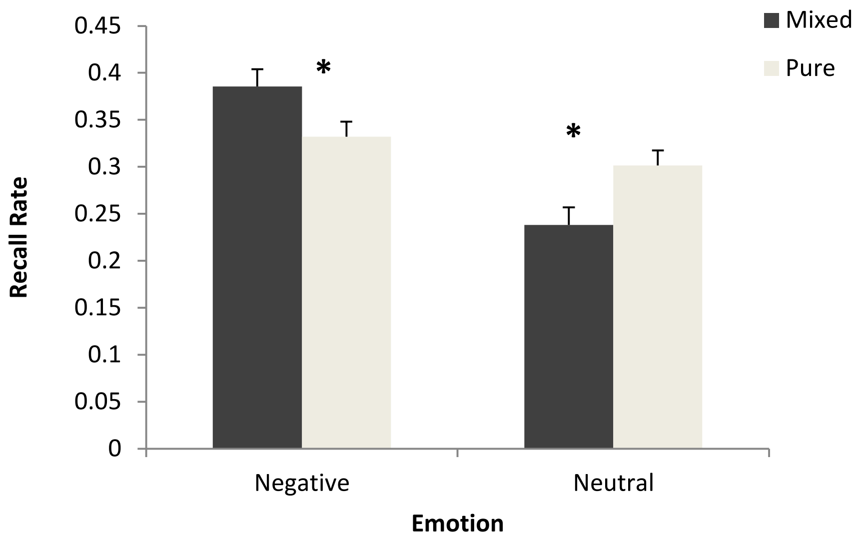

Figure 3.2: Mean recall rate by Emotion and List type. Error bars represent standard error of the mean.

Analysis on the SAM valence ratings recorded during the study were also computed and revealed a significant main effect of Emotion [$F(1, 33) = 741.19$, $p < .001$, $\eta p^2 = .96$], indicating expectedly that negative images were rated as more negative than neutral images (negative images: mean = 4.14, SD = 0.27; neutral images: mean = 2.85, SD = 0.16). Analysis on the response time for the SAM judgement task revealed a significant interaction between Emotion and List [$F(1, 33) = 8.23$ $p < .01$, $\eta p^2 = .199$]. However, subsidiary analysis revealed this to be driven by a marginally significant main effect of List in the neutral image condition [$F(1, 33) = 4.21$, $p = .048$, $\eta p^2 = .13$] as the mean RT in the neutral mixed condition was 861.27ms (SD = 397.91ms), whereas the mean neutral pure RT was 919.62ms (SD = 418.81ms). A main effect of List was not significant for negative items (*ps* > .10) and there were no main effects of Emotion for mixed or pure lists (*ps* > .05). As the difference in RT between lists in the neutral condition was only marginally significant and there were no other significant main effects, this is not considered as a confounding factor in the results.

3.3.1.2. Arousal Recall

A List x Arousal (high-arousal, low-arousal, neutral) within-subjects ANOVA was performed on the recall rates and revealed as expected a significant main effect of Arousal [$F(2, 66) = 60.942$, $p < .001$, $np^2 = .649$, $\varepsilon = .91$], reflecting the higher proportion of items recalled in the high-arousal condition, compared to the low-arousal and neutral condition (see Figure 3.3). There was no main effect of List type ($F < 1$). There was however an interaction between Arousal X List [$F(2, 66) = 21.957$, $p < .001$, $np^2 = .40$, $\varepsilon = .84$], which when examining the mean recall rate for each condition, appears to have been the result of differential recall rates between mixed and pure lists in the high-arousal and neutral condition (see Figure 3.3). This is consistent with the hypothesis, whereby there is a reduction in the amount of images recalled in the mixed-neutral condition. This also supports the results from the previous recall section, whereby the mixed-negative condition had a significantly higher proportion of recall compared to the pure list; this appears to have been driven by a higher recall for mixed-high-arousal, compared to pure-high-arousal ($t(33) = 3.825$, $p < 0.001$, as there was no significant difference between the mixed-low-arousal and pure-low-arousal recall rates ($t(33) = 1.23$, $p = .228$). Further Paired sample t-tests showed there was a significant difference between all three arousal levels in the mixed-list condition (*ps* < .001); with high-arousal having the highest level of recall (mean = .45, SD = .09), followed by low-arousal (mean = .33, SD = .10), then neutral (mean = .24, SD = .08). However, in the pure-list condition paired sample t-tests only revealed a significant difference between high arousal (mean = .39, SD = .13) vs low arousal (mean = .31, SD = .10) and high arousal vs neutral arousal (mean = .30, SD = .08) (*ps* < .001); with low-arousal and neutral items having comparable level of recall (*ps* = .769).

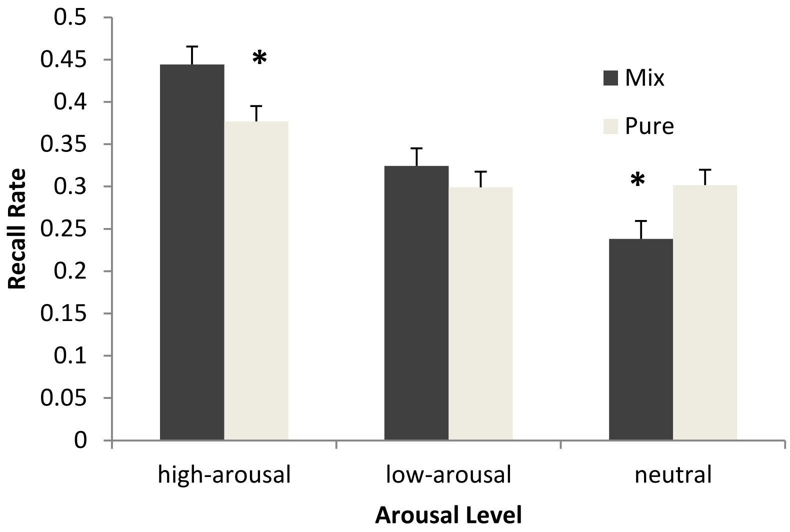

Figure 3.3: Mean recall rate by Arousal and List type. Error bars represent standard error of the mean.

3.3.2 Individual differences

3.3.2.1 Ospan

To establish if WMC had an effect on recall, the recall rates were first subject to a median split based on OSPAN scores (Elward, Evans & Wilding, 2013; see Appendix C for OSPAN raw data scores and descriptive data). An Emotion X List X OSPAN-score mixed ANOVA (OSPAN-score, between subjects factor) revealed a significant main effect of Emotion [$F(1, 32) = 58.90$, $p < .001$, $np^2 = .648$] and an interaction between Emotion X List [$F(1, 32) = 64.991$, $p < .001$, $np^2 = .670$], in a replication of the previous behavioural analysis. There were no significant effects involving OSPAN-score ($F < 1$). This suggests WMC has no effect upon recall rate in this study. To confirm these results, Paired sample t-tests showed no difference between subjects with high-OSPAN vs low-OSPAN scores (see Figure 3.4), across any of the main conditions ($ps > .1$).

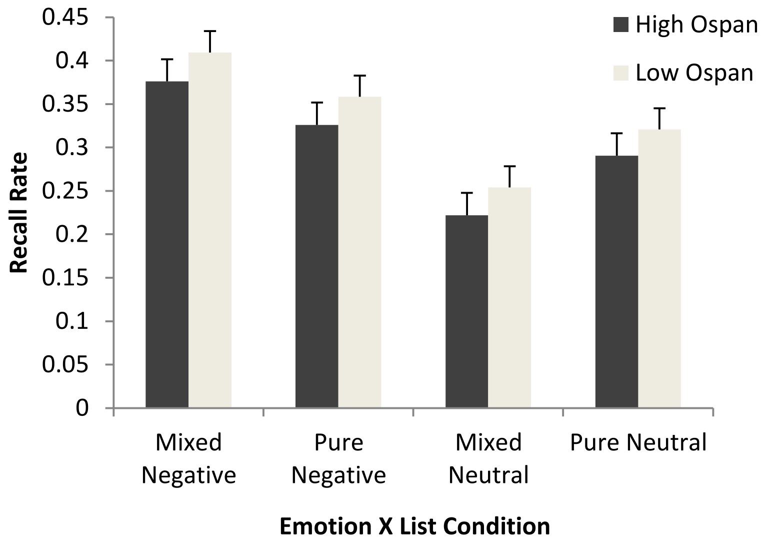

Figure 3.4: Mean recall rate by Ospan-score, across the four key conditions. Error bars represent standard error of the mean.

3.3.2.2 Emotional Regulation

A Kendall's Tau correlation statistic was first computed to asses if the ERQ was measuring reappraisal and suppression as independent constructs; it confirmed there was no significant association between reappraisal and suppression scores (*ps* = .147) and the two constructs could be treated as independent (Gross & John, 2003).

Following the methods outlined in the Methods (see 3.2.5 Controlling for individual differences, Chapter 3), to establish if the emotion regulation strategy had an effect on recall performance the Reappraisal scores were subject to a median split to assign individuals to either a high-reappraisers group or a low-reappraisers group (see appendix D for raw Repression and Suppression scores and resulting scores of median split). The corresponding recall scores of the high-appraisal group and the low-appraisal group were then entered into a mixed ANOVA of Emotion X List X Reappraisal-score (high versus low reappraisers, as a between subjects factor). The results revealed similar to previous analysis, a main effect of Emotion [$F(1, 32) = 58.251$, $p < .001$, $np^2 = .645$] and a significant interaction between Emotion X List [$F(1, 32) = 65.901$, $p < .001$, $np^2 = .673$]. No effects involving the factor of Reappraisal-score were significant ($F < 1$), as the mean recall across all conditions was comparable for high-reappraisers (HR) and low-reappraisers (LR) (mixed-negative mean (HR) = .38, SD = .07, (LR) = .41, SD = .08; mixed-neutral mean (HR) = .22, SD = .09, (LR) = .25, SD = .08; pure-negative mean (HR) = .32, SD = .09, (LR) = .37, SD = .12; pure-neutral mean (HR) = .29, SD = .08, (LR) =

.33, SD = .08). This confirms the previous findings about Emotion and list type and supports the hypothesis that reappraisal has no effect upon recall performance (Gross, 2002).

Following the same method as above, the Suppression scores were subject to a median split and individuals were assigned to either a high-suppressor group or a low-suppressor group (see appendix D). The corresponding recall rates for these two groups were then entered into a mixed ANOVA, Emotion X List X Suppression-score. The results revealed again, a main effect of Emotion [$F(1, 32) = 58.604$, $p < .001$, $np^2 = .647$] and a significant interaction between Emotion X List [$F(1, 32) = 65.734$, $p < .001$, $np^2 = .673$]. However, no effects involving the suppression-scores were significant ($F < 1$), again with the mean recall across all conditions comparable between high-suppressors (HS) and low-suppressors (LS) (mixed-negative mean (HS) = .41, SD = .1, (LS) = .37, SD = .05; mixed-neutral mean (HS) = .26, SD = .09, (LS) = .21, SD = .07; pure-negative mean (HS) = .36, SD = .11, (LS) = .33, SD = .10; pure-neutral mean (HS) = .33, SD = .08, (LS) = .29, SD = .08. These results do not support the hypothesis, which posited that suppression should significantly reduce recall (specifically for negative items).

These results therefore suggest that neither reappraisal nor suppression, have had an impact upon memory recall performance.

3.3.2.3 Big Five Inventory

Analysing the scores for the Big Five Inventory, it was found 4 participants had scores more than 3 standard deviations away from the mean (one participant for Agreeableness score; one participant for Openness score; two participants for Conscientiousness scores), therefore they were excluded from this section of the analysis (see appendix E for raw Big Five personality inventory scores and descriptive data). Testing the normality of the five traits measured showed that Agreeableness, Conscientiousness and Openness were not normally distributed [$W(30)= .875, .925, .906$, $p = .002, .035, .012$], therefore non-parametric correlations were computed.

To assess if the Big Five traits were associated with recall, statistical correlations using the Kendall's tau-b and recall performance across the four key conditions were calculated; however, they revealed no significant correlations (see Table 3.1)

Table 3.1. Kendall's tau-b Correlations between the Big Five personality traits and recall performance across the four key conditions.

Big Five personality traits	**Memory Recall Condition**			
	Mixed Negative	Mixed Neutral	Pure Negative	Pure Neutral
Openness	.044	-.046	-.002	-.119
Conscientiousness	.102	.223	.106	.196
Extraversion	-.079	.026	-.158	-.017
Agreeableness	.078	.114	.065	.092
Neuroticism	.044	-.046	-.017	-.119

N = 30

These results suggest that the personality traits defined by the Big Five inventory do not have any effect upon the recall performance across any of the key conditions.

3.3.2.4 Behavioural Inhibition System and Behavioural Activation System (BIS BAS)

The results of the BIS BAS questionnaires were computed to create a global BIS and global BAS score as well as separate BAS-Drive, BAS-Fun seeking and BAS-Reward scores (see appendix F for raw BIS BAS scores and descriptives data). Normality tests revealed BAS-Fun seeking and BAS-Reward were not normally distributed [W(34)= .936, .927, p = .047, .026] and given the ordinal scale of the data, it was decided to calculate subsequent correlations using the Kendall's tau-b statistic.

To establish if there was a relationship between BIS BAS scores and recall performance across the four key conditions, correlational analysis revealed there to be no significant associations between BIS BAS scores and recall performance (see Table 3.2.). Additional analysis was also performed on the BAS scores, by separating them into three sub-factors of BAS-Drive, BAS-Fun seeking and BAS-Reward scores. Correlational analysis on these three sub-factors again did not reveal any significant relationship between recall performance and BAS scores (see Table 3.2).

Table 3.2 Kendall's tau-b correlations between the BIS BAS scores and recall performance across the four key conditions.

BIS BAS scores	Memory Recall Condition			
	Mixed Negative	Mixed Neutral	Pure Negative	Pure Neutral
BIS (global)	.074	-.164	-.011	-.080
BAS (global)	-.050	-.104	-.032	.080
BAS-Drive	-.107	-.157	-.040	.033
BAS-Fun seeking	.018	-.043	-.052	-.037
BAS-Reward	.106	.078	.108	.172

N = 34

These results suggest there is no significant relationship between any BIS BAS scores and recall performance across the four key conditions, in this study.

3.3.3 ERP Results

3.3.3.1 Encoding

A visual inspection of the data shows a robust overall Dm effect, whereby there is a pronounced differentiation between the waveforms for subsequently remembered and subsequently forgotten items (see figure 3.5). The overall Dm effect starts around ~250ms and extends to the end of the recorded epoch at 1500ms. In accordance with the results obtained in Experiment One (See 2.4.3 ERP Results, Chapter 2), the Dm effect appears strong overall, however the Dm effect for neutral-mixed items seems to be diminished, specifically across posterior sites. A closer examination of the posterior waveforms suggests that this reduction in the Dm effect for neutral-mixed items appears to be the strongest in an early (pre~ 400ms) and a later sustained positivity (post ~ 900ms). Unlike the previous experiment, the closer visual inspection of the waveforms shows that for the negative-pure (and to a lesser extent neutral-pure) condition, the Dm is not fully sustained to the end of the recorded epoch. The Dm effect in the pure condition appears to end ~1100ms.

The statistical analysis will test if the visual inspection which revealed a cancellation of Dm activity for neutral-mixed items, is reliable and test in what time window the Dm effect in the negative-pure condition, is reliable.

200-400

An Emotion X Memory X List X A-P X Laterality within subjects ANOVA revealed a significant main effect of Memory [$F(1, 33) = 17.23$, $p < .001$, $\eta p^2 = .34$], which indicates an overall larger positivity for subsequently remembered items compared to subsequently forgotten items. The ANOVA also confirmed a significant main effect of Emotion [$F(1, 33) = 29.095$, $p < .001$, $\eta p^2 = .47$], showing that negative items have an overall larger positivity compared to neutral items.

To meet the hypothesis of this study and to focus on replicating the effects of the previous study (see Chapter 2), as outlined in the methods (see 3.2.9 Statistical analysis, Chapter 3) effects involving the factors of Emotion, Memory, List and A-P were preferentially targeted. As such, the ANOVA revealed a near to significant interaction between Emotion X Memory X List [$F(1, 33) = 3.608$, $p = .066$, $\eta p^2 = .099$], which indicates these factors are interacting somewhat, however not to a significant level. In addition, the ANOVA also revealed a complex interacting between Emotion X Memory X A-P X Laterality [$F(1, 33) = 4.555$, $p < .05$, $\eta p^2 = .12$].

Given the replication nature of this study, as mentioned in the methods above (see 3.2.1 Methods, Chapter 3) this study requires more statistical power (Button et al., 2013) so it was decided to focus the analysis on the key factors of Emotion, Memory, List and A-P. Hence, to elucidate the above interactions the data was split via A-P and an Emotion X Memory X List ANOVA was computed. This ANOVA at anterior sites revealed a significant main effect of Memory ($ps < .001$), reflecting the overall effect of Memory above. There was also an interaction between Emotion X Memory X List [$F(1, 33) = 11.358$, $p = .002$, $\eta p^2 = .256$]. Similarly this ANOVA at posterior sites also revealed a significant main effect of Memory ($ps = .005$) and significant three way interaction between Emotion X Memory X List [$F(1, 33) = 3.856$, $p = .058$, $\eta p^2 = .105$]. To break down these interactions an Emotion X Memory ANOVA was computed separately for each list type. This ANOVA revealed a significant Emotion X Memory interaction for the mixed-list condition only, at both anterior [$F(1, 33) = 12.981$, $p = .001$, $\eta p^2 = .282$] and posterior [$F(1, 33) = 21.374$, $p < .001$, $\eta p^2 = .393$] sites. The same interaction was not significant for the pure-list condition at either anterior [$F < 1$] or posterior [$F < 1$] sites. To elucidate these interactions for the mixed-list conditions a final one factor Memory ANOVA was computed. Despite the significant Emotion X Memory interaction at anterior sites, it was found that Memory was significant for both negative [$ps < .001$, $\eta p^2 = .362$] neutral [$ps = .054$, $\eta p^2 = .108$] items. However at posterior sites, it was found the interaction was driven by a significant main effect of Memory for negative items only [$ps < .001$, $\eta p^2 = .397$], as Memory for neutral items was not significant [$ps = .992$, $\eta p^2 = .00$].

These findings demonstrate results similar to those in the previous chapter (see Chapter 2), showing that the Dm effect in this time window is strong across all conditions, except in the neutral-mixed condition, where the Dm effect in posterior sites is non-significant and therefore cancelled.

400-800

Computing the same 5-way general ANOVA on the 400-800ms time window, confirmed a significant main effect of Memory [$F(1, 33) = 38.258$, $p < .001$, $\eta p^2 = .537$] and Emotion [$F(1, 33) = 57.819$, $p < .001$, $\eta p^2 = .637$]; reflecting the larger positivity for subsequently remembered items compared to forgotten items and the larger positivity for negative compared to neutral items. Similar to the previous time window, to address the replication hypothesis of this study and meet the additional statistical power needs (Button et al., 2013), effects involving the key factors of Emotion, Memory, List and A-P were targeted. As such there were two key interactions, involving Emotion X Memory X AP [$F(1, 33) = 5.20$, $p = .029$, $\eta p^2 = .136$] and Memory X List X AP [$F(1, 33) = 3.957$, $p = .055$, $\eta p^2 = .39$].

To elucidate both these interactions it was decided to divide the data by A-P and conduct an Emotion X Memory x List ANOVA. The analysis revealed a significant interaction between Emotion X Memory X List for both anterior [$F(1, 33) =6.577$, $p = .015$, $\eta p^2 = .166$] and posterior [$F(1, 33) =12.906$, $p = .001$, $\eta p^2 = .281$] sites. The analysis revealed a significant interaction between Emotion X Memory X List for both anterior [$F(1, 33) =6.577$, $p = .015$, $\eta p^2 = .166$] and posterior [$F(1, 33) =12.906$, $p = .001$, $\eta p^2 = .281$] sites. Subsidiary analysis indicated these significant interaction were driven by an Emotion X Memory interaction for anterior-mixed [$F(1, 33) = 17.328$, $p < .001$, $\eta p^2 = .344$] and posterior-mixed [$F(1, 33) = 63.679$, $p < .001$, $\eta p^2 = .659$] but not for anterior-pure ($F < 1$) or posterior-pure ($ps = .154$), where only the main effects of Memory (both $ps > .005$) and Emotion (both $ps > .001$) were significant. Breaking down these Emotion X Memory interactions for the mixed-list conditions found they were driven by significant effects of Memory for negative items at both anterior ($ps < .001$, $\eta p^2 = .406$) and posterior ($ps < .001$, $\eta p^2 = .694$) sites, whereas Memory for neutral items were non-significant at both anterior ($ps = .098$, $\eta p^2 = .081$) or posterior ($ps = 0.06$, $\eta p^2 = .103$) sites.

These findings support the patterns of results observed in the previous time window, whereby the Dm effect is robust across most conditions, except for mixed-neutral. In this time window both the anterior and posterior sites for mixed-neutral are non-significant, reflecting the cancellation of the Dm effect observed in the earlier 200-400ms time window.

800-1500

Statistical analysis using the same general ANOVA of Emotion X Memory X List X A-P X Laterality, revealed a significant main effect of Memory [$F(1, 33) = 21.961$, $p < .001$, $\eta p^2 = .431$], Emotion [$F(1, 33) = 28.189$, $p < .001$, $\eta p^2 = .493$] and A-P [$F(1, 33) = 29.588$, $p < .001$, $\eta p^2 = .505$], as was observed in the two earlier time windows. The ANOVA also confirmed a significant interaction combining the main factors concerning the hypothesis with an Emotion X Memory X List interaction [$F(1, 33) = 6.356$, $p = .017$, $\eta p^2 = .180$]. As with the previous time windows, to give power to this replication study (Button et al., 2013) it was decided to include the factor of A-P in the subsidiary analysis and divide the data by A-P to compute further Emotion X Memory X List ANOVA.

As with the previous time window, to elucidate these main effects and interaction, the data was split by A-P (anterior and posterior) and an Emotion X Memory X List ANOVA computed. This ANOVA showed there to be a significant interaction of Emotion X Memory X List for both the anterior [$F(1, 33) = 5.20$, $p = .029$, $\eta p^2 = .136$] and posterior [$F(1, 33) = 5.20$, $p = .029$, $\eta p^2 = .136$] sites. To help interpret these results, subsidiary analysis revealed these interactions to have been driven by an Emotion X Memory significant interaction for anterior-mixed [$F(1, 33) = 13.658$, $p < .001$, $\eta p^2 = .293$] and posterior-mixed [$F(1, 33) = 15.34$, $p < .001$, $\eta p^2 = .317$] sites, whereas anterior-pure ($ps = .213$) and posterior pure sites were not significant ($ps = .799$), as was also shown in the previous time windows. However, in this time window the posterior-pure sites did not exhibit a main effect of Memory ($ps = .112$).

Breaking down these interactions to the main effect of Memory, showed both anterior and posterior mixed-negative to be significant ($ps <.001$, $\eta p^2 = .414$; $ps < .001$, $\eta p^2 = .436$) and anterior mixed-neutral to be significant ($ps = 0.005$, $\eta p^2 = .212$). Whereas posterior mixed-neutral was not significant ($ps = .220$, $\eta \mathrm{p}^2 = .045$), reflecting the results previously observed indicating the cancellation of the Dm effect for mixed-neutral items in posterior regions. Looking further into the non-significant main effect of Memory in posterior-pure sites revealed Memory to be non-significant for both negative ($ps = .314$, $\eta \mathrm{p}^2 = .031$) and neutral items ($ps = .106$, $\eta \mathrm{p}^2 = .077$).

To summarise, these results support the effects observed in the earlier time windows and previous experiment (see Chapter 2) showing a strong Dm effect across most conditions, except in the mixed-neutral condition where there is a cancellation of the Dm effect in posterior regions. However, unlike in previous time windows there was also a reduction in the Dm effect in both pure-negative and pure-neutral (although less pronounced) across posterior sites.

800-1100 and 1100-1500

In order to better understand what is happening to the Dm effect in the pure list conditions within the previous time window, it was decided to break down the time window into a further two sections (800-1100ms and 1100-1500ms) and compute the statistical analysis again for pure lists only. Splitting the data across A-P (anterior and posterior sites) and computing statistical analysis on the 800-1100 time window revealed as expected, a strong significant main effect of Emotion for both pure-anterior [$F(1, 33) = 30.881$, $p < .001$, $\eta p^2 = .483$] and pure-posterior sites [$F(1, 33) = 35.556$ $p < .001$, $\eta p^2 = .519$]; but, crucially it also confirmed a significant main effect of Memory for both pure-anterior [$F(1, 33) = 13.22$, $p < .001$, $\eta p^2 = .286$] and pure-posterior sites [$F(1, 33) = 5.459$, $p = .026$, $\eta p^2 = .142$]. As shown in the 800-1500 time window, there were no significant interactions between Emotion X Memory for anterior or posterior sites (*ps* = .774; *ps* = .766). These results confirm that the Dm effect across the pure-negative and pure-neutral conditions exists up until 1100ms, across both anterior and posterior sites.

Conducting the same analysis on the 1100-1500ms time window also revealed a significant main effect of Emotion across anterior (*ps* = .007) and posterior (*ps* = .003) sites, as anticipated. However, although there was again a significant main effect of Memory at the anterior sites (*ps* = .002), it did not reach significance at posterior sites (*ps* = .283). The interaction between Emotion X Memory was not significant at posterior sites (*ps* = .555) although it was close to significance at anterior sites (*ps* = .080). To understand these effects better, subsidiary analysis confirmed that neutral-anterior items had a significant effect of Memory [$F(1, 33) = 11.875$, $p = .002$, $\eta p^2 = .265$]; however negative-anterior (*ps* = .105), negative-posterior (*ps* = .660) and neutral-posterior (*ps* = .186) sites did not show a main effect of Memory. These results show that the Dm effect for pure-negative items does not stretch beyond 1100ms to the end of the recorded epoch, across both anterior and posterior sites; whereas, for pure-neutral items there Dm effect is still strong across anterior sites, but like pure-negative items, it too does not stretch beyond 1100ms across posterior sites.

To summarise these results show the Dm effect is still strong in both pure-negative and pure-neutral items in the 800-1100ms time window. However post 1100ms, the Dm effect is no longer significant for pure-negative items globally across the electrode sites. The effects are less pronounced for pure-neutral items, with the Dm effect still significant across anterior but not at posterior sites. These results support the initial visual inspection of the waveforms and show that the Dm effect for pure-negative (and to a lesser extent, pure-neutral) items is not sustained over the whole tested epoch and appears to end around 1100ms.

In summary, these results support our hypothesis and the results of the previous experiment. Whereby there is a robust Dm effect across most conditions, except in the mixed-neutral condition where the Dm effect is cancelled, specifically in posterior regions. In contrast to previous results (see Chapter, 2) however, the Dm effects for pure list conditions are not sustained across the whole recorded epoch; with the Dm effect no longer being significant for pure-negative items across all sites and for pure-neutral items at posterior sites, post 1100ms.

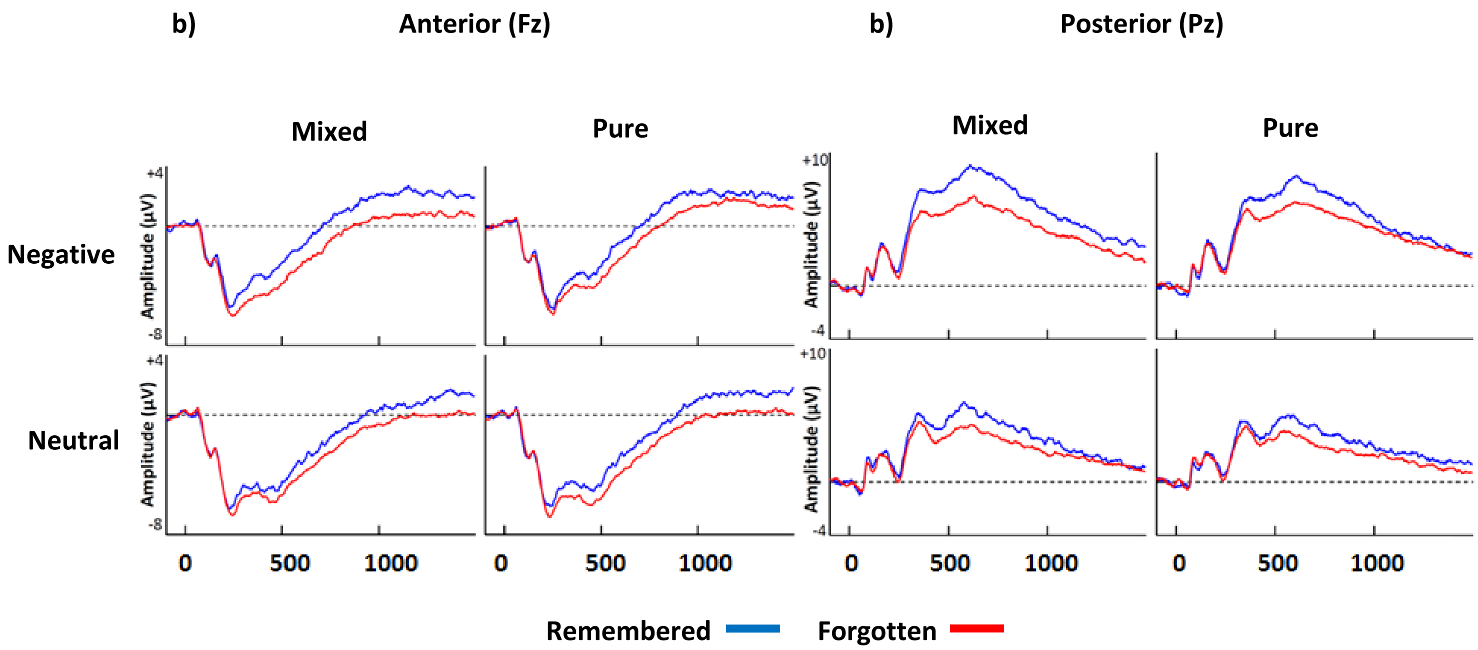

Figure 3.5: a) ERP waveforms plotted on electrode Fz for encoding-related activity separated according to subsequent memory (Remembered vs. Forgotten) and picture content (Negative vs. Neutral).Amplitude in microvolts (µV) is on the *y* axis and time in milliseconds is on the *x* axis. b) ERP waveforms plotted on electrode Pz for encoding-related activity separated according to subsequent memory (Remembered vs. Forgotten) and picture content (Negative vs. Neutral).

3.3.3.2 Arousal data

To address the possibility that the Dm effects achieved for negative items was not due to a confound between subsequent memory and arousal levels, a series of Memory X List X A-P X Laterality within subjects ANOVAs were performed for both the high-arousal and low-arousal subsets of data. They showed a main effect of memory across all time windows (200-400, 400-800 and 800-1500) for both high-arousal items [200-400: $F(1,24) = 5.88$, $p = .023$, $np^2 = .197$; 400-800: $F(1,24) = 16.198$, $p < .001$,

np^2 = .403; 800-1500: $F(1,24) = 4.176$, p =.052, np^2 = .148] and low-arousal items [200-400: $F(1,24)$ = 6.931, p =.015, np^2 = .224; 400-800: $F(1,24) = 12.987$, $p < .001$, np^2 = .351; 800-1500: $F(1,24) = 7.750$, p =.010, np^2 = .244]. These results show the Dm effect is robustly observed for negative items independently across both high-arousal and low-arousal subgroups (see figure 3.6); suggesting there is no evidence the Dm effect observed in negative items is the result of an effect of a confound between subsequent memory and arousal.

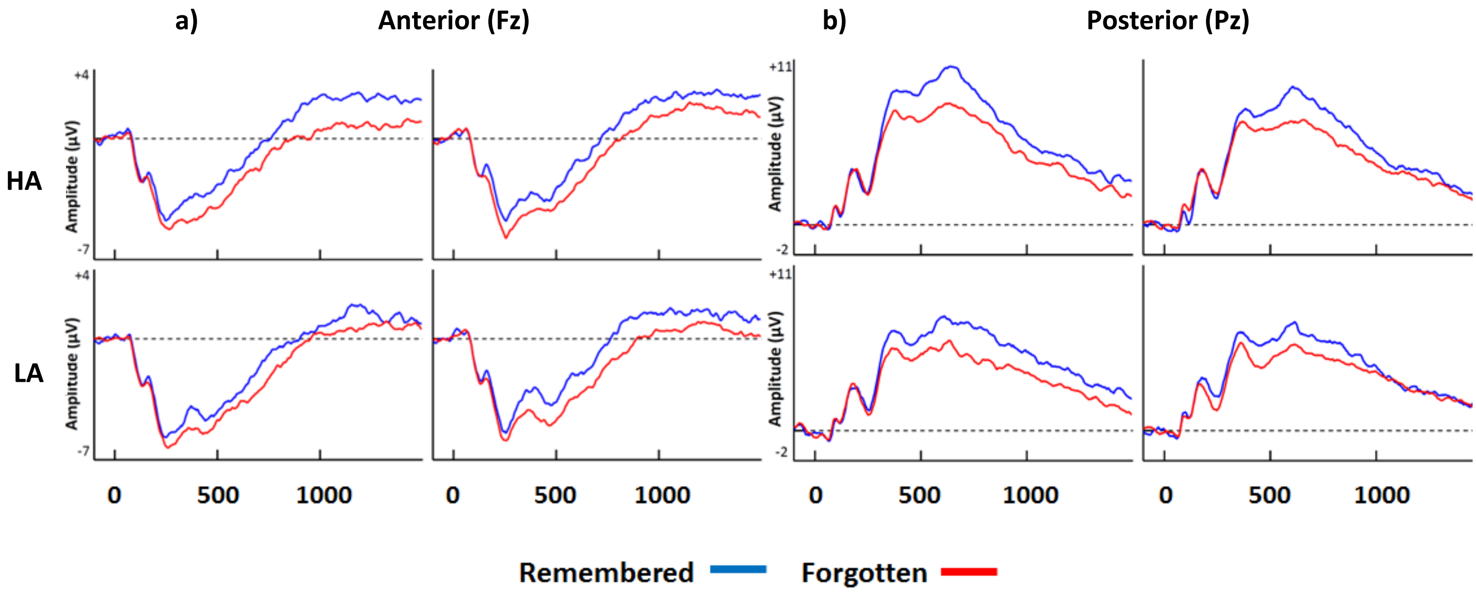

Figure 3.6: The Dm effect separately for high arousal (HA) and low arousal (LA) groups at anterior (Fz) and posterior (Pz) electrode sites.

3.3.4 Individual differences

To obtain a neural index of encoding, difference scores (known as the Dm effect) between ERP's for subsequently remembered items and subsequently forgotten items (Paller & Wagner, 2002) were computed for each of the key conditions (mixed-negative, mixed-neutral, pure-negative and pure-neutral), in the three main time windows (200-400,400-800 and 800-1500), across anterior and posterior scalp regions . Similar to previous studies and research using personality measures correlational analysis was used (Walker et al., 2011; Gray et al., 2005; Canli et al., 2001; Komarraju, et al., 2011; Schaefer et al., 2006), whereby each difference score was then correlated with the measures of individual differences, noted below. If no significant effects were found at the regional scalp level, then all the regional scalp clusters were averaged into a whole-scalp cluster (Walker et al., 2011), which was again correlated with the measures of individual difference. It must however be noted, the correlational analyses described below has low statistical power, due to a sample size of only 40 participants. The analysis on the Big Five Inventory analysis also 4 outliers, therefore this set of analysis had particularly low statistical power. Based on this, caution must be applied when drawing conclusions from the analysis below.

3.3.4.1 Ospan

In the 200-400 time window, Pearson's correlations between the Dm effects and OSPAN scores revealed a significant positive correlation between posterior-mixed-neutral and OSPAN scores [$r(34) = .407$, $p = .017$]; however no other conditions were significant ($p > .250$) so regional scalp clusters were averaged into whole-scalp clusters and the correlations recomputed. The results revealed a significant correlation between the mixed-neutral Dm effect and OSPAN scores $r(34) = .363$, $p = .044$], but no other conditions were significant (all $p > .30$).

Correlational analysis for the 400-800 and 800-1500 time windows did not reveal any significant associations (see appendix C for individual correlation statistics, across all conditions) at neither the regional scalp clusters (400-800: all $p > .10$; 800-1500: all $p > .10$) nor the whole-scalp clusters (400-800: all $p > .10$; 800-1500: all $p > .20$).

These findings overall support the behavioural results and do not provide evidence to suggest OSPAN scores robustly correlate with the neural index for encoding. Early time windows do show a significant correlation between the Dm effect of posterior-mixed-neutral and mixed-neutral clusters with OSPAN scores, suggesting that in some way a higher OSPAN score and WMC protects against the early cancellation of the mixed-neutral Dm effect. These results could be interpreted in line with the findings of WMC and visual attention (literature) and are discussed in more detail in the discussion.

3.3.4.2 Emotional Regulation

The scores from the Emotion Regulation questionnaire were separated into scores of Reappraisal and scores of Suppression (see appendix D), for each participant. Kendall's tau-b correlations were then computed between these Reappraisal and Suppression scores and the key regional scalp regions, across the three time windows. These correlations did not reveal any significant effects (see appendix D for individual correlation statistics) between Reappraisal or Suppression scores and the key scalp regions at the 200-400 (Reappraisal all $p > .200$; Suppression all $p > .05$), 400-800 (Reappraisal all $p > .200$; Suppression all $p > .05$) or 800-1500 (Reappraisal all $p > .05$; Suppression all $p > .10$) time windows. The regional scalp clusters were then averaged to whole-scalp clusters and the correlations still revealed no significant effects at any of the key time windows (200-400: Reappraisal all $p > .200$; Suppression all $p > .100$; 400-800: Reappraisal all $p > .100$; Suppression all $p > .200$; 800-1500: Reappraisal all $p > .100$; Suppression all $p > .400$).

These results do not support the hypothesis and mirror the findings from the behavioural section, again suggesting that neither reappraisal nor suppression has an association with memory encoding across any of the key conditions.

3.3.4.3 Big Five Inventory

Analysing the scores of the Big Five Inventory showed there to be four outliers, which were excluded from subsequent analysis in this section (see Behavioural Results). Correlations between the five traits of the Big Five were computed against the Dm effect for each of the key conditions. The Kendall's tau-b correlations in the 200-400 time window revealed significant negative correlations between Extraversion and anterior-mixed-negative [$\tau(30) = -.295$, $p = .026$] and Extraversion and posterior-mixed-negative [$\tau(30) = -.343$, $p = .010$]. No other traits revealed significant effects with any of the key scalp regions (see appendix E for individual correlation statistics) so the scalp regions were averaged into whole-scalp regions. Analysis upon whole-scalp regions showed a significant negative correlation between Extraversion and the Dm for mixed-negative [$\tau(30) = -.371$, $p < .01$].

The same analysis was computed for the 400-800 time window and revealed no significant correlations at the regional scalp clusters or the whole-scalp cluster level (see appendix E).

Correlational analysis on the final 800-1500 time window did reveal a significant negative correlation between Extraversion and posterior-pure-neutral [$\tau(30) = -.362$, $p < .01$]. No other significant correlations were found between the Five traits and regional scalp clusters, so they were averaged into a whole-scalp cluster; however, analysis revealed no further significant correlations (all $p > .05$).

These results show Extraversion does significantly correlate with the mixed-negative Dm effect at early time windows and the posterior-pure-neutral Dm effect in later time windows, however no other traits were found to have an association with any of the key conditions, across any time window. This suggests that overall, as was shown in the behavioural results; there is no robust relationship between the personality traits, as defined by the Big Five inventory, and memory encoding.

3.3.4.5 BIS BAS

Correlational analysis in the 200-400 time window upon the regional scalp clusters, did not reveal any significant relationships (see appendix F for individual correlation statistics) between the global

BIS or global BAS scores and the key conditions (all $p > .100$). Separating the BAS scores into BAS-Drive, BAS-Fun seeking and BAS-reward, also did not reveal any significant associations at the region scalp cluster level (all $p > .05$), therefore the regions were averaged into a whole-scalp cluster. This analysis again did not reveal any significant correlations between the key conditions and global BIS and BAS scores (all $p > .100$); however analysis on the three sub-factor BAS scores, did surprisingly reveal a significant correlation between BAS-Fun seeking and the mixed-negative Dm effect [$\tau(34) = .251$, $p = .049$]. No other sub-factors revealed significant correlations with the whole-scalp cluster key conditions (all $p > .100$).

Continuing this analysis into the 400-800 time window, correlations computed upon regional scalp clusters did not reveal any significant associations between either global BIS or BAS score (all $p > .200$), nor within any of the three BAS sub-factors (all $p > 0.05$). Although the averaged whole-scalp region, again did not reveal any significant relationships between the global BIS and BAS scores (all $p > .100$), the analysis did reveal significant correlations between BAS-Drive and the pure-neutral Dm effect [$\tau(34) = -.299$, $p = .018$] and BAS-Fun seeking and the pure-neutral Dm effect [$\tau(30) = .253$, $p = .047$].

Correlational analysis on the final 800-1500 time window did not reveal any significant effects between the global BIA and BAS scores (all $p > .200$), using regional scalp clusters. The sub-factors of the BAS scores, did however show significant negative correlations between BAS-Drive and anterior-mixed-neutral [$\tau(34) = -.257$, $p = .041$] and BAS-Drive and posterior-pure-neutral [$\tau(34) = -.390$, $p = .002$]. Breaking these regional clusters down to whole-scalp clusters confirmed these findings with a significant negative correlation between BAS-Drive and the pure-neutral Dm effect [$\tau(34) = -.337$, $p = .008$]. No other whole-scalp correlations reached significance level (all $p > .05$).

To summarise, these results did not show any significant relationships between global BIS and BAS scores and the key regions and conditions. However when the BAS scores were broken down into the three sub-factors, the results did show some isolated significant results, however they were not consistent across conditions or time windows.

Overall, as with the individual difference scores and recall performance, these results do not show evidence for any measure of personality robustly having an effect upon the Dm effect across any key scalp regions or conditions. There are some individual small effects within each of the individual difference measure, however these effects are isolated to certain time windows and often not in the expected conditions; suggesting these findings are not strongly influencing the Dm effects across the key conditions. The results are discussed in more detail in the discussion section.

3.4 Discussion

3.4.1 Main Findings

These results support the findings of the previous research (Watts et al., 2014) and the experimental hypothesis, demonstrating that the recall performance for neutral items was lower in the mixed-list condition compared to the pure-list condition. This effect was mirrored in the ERP results, with a reduced Dm effect for neutral items in the mixed-list condition, specifically in posterior regions. This supports the notion that the EEM effect is driven by a mechanism of disruption of encoding processes surrounding neutral items, when they are presented in intermixed lists alongside negative items; due to the fact negative items preferentially capture the majority of processing resources leaving little or no resources left to processes and enable the encoding of neutral items. These effects were observed primarily in an early 200-400 and later 800-1500 time window; although the specific factors involved in the interaction were not the same as the previous study (Watts et al., 2014). The main expectation for both the previous study and this present study was to find significant interactions involving the factors of Emotion, Memory and List type; the previous study found significant interactions between Memory, Emotion, List and A-P, whereas this study only found significant main interactions between Emotion, Memory and List and Emotion, Memory, A-P and Laterality. However the Dm effect is known to change in spatial and temporal properties across studies (Paller & Wagner, 2002) and when the interactions in this present study were broken down, the driving factors behind the interaction were found to be due to the factor of Memory and a cancellation of the Dm effect for mixed-neutral items; the same driving factors as in the previous experiment (Watts et al., 2014).

This evidence supports the two-step process proposed in the previous study (Watts et al., 2014). The morphology of the early ERP effects observed in the 200-400 time window support the idea of an initial relevance detection, which is the first step to the process. This mechanism would determine if a given stimulus is relevant to the ongoing task or to our goals, thus allowing the preparation of additional resources needed to process the stimulus. This explanation is supported by other studies which have observed early Dm effects, interpreted as early attentional resources that process stimuli and aid encoding (Mangels et al., 2001; Duarte et al., 2004). The early P3 effect, as observed in this study, has been suggested to be related to attentional processes (Polich, 2007) and evidence shows it can have the centro-parietal site distribution (Ferrari, Bradley, Codispoti & Lang, 2010) that we see in our results. This P3-like effect observed in this present study and previous study (Watts et al., 2014) is thought to reflect the first step in this two-step process, whereby there is an initial call for resources, which reflects the focal engagement of attention on task relevant items that will require additional or enhanced processing (Schupp, Flaisch, Stockburger & Junghofer, 2006); this step of resource demanding processes is likely to primarily involve aspects of cognitive control and working memory processes.

This present study investigated further the ERP effects happening between 400-800ms. Similar to the previous study (Watts et al., 2014), there were no significant interaction in this time window involving the key factors of Emotion, Memory, List and A-P; however there were two smaller interactions involving Emotion, Memory and A-P and another involving Memory, List and A-P. Based on a visual inspection of the data and the interactions found, it was decided to investigate these effects further, following the same breakdown as the earlier 200-400 time window. The results revealed similar patterns to the earlier time window, whereby there was a robust Dm effect observed for all conditions except for mixed-neutral items. The effect in this time window however were marginal with noticeably smaller effect sizes; suggesting that the Dm effect for neutral items in this time window was reduced, rather than being cancelled as observed in the early and later time windows. Although this finding was not observed in the previous study (Watts et al., 2014), the literature has shown ERP effects sensitive to affective pictures tend to be predominant between 400-800ms and reflects post-perceptive attentional responses (Codispoti et al., 2012). This would also fit with the two-step theory proposed, whereby, after the initial call for resources, there is a post-perceptive attentional response to the stimuli that require enhanced processing. Namely this reflects the negative items and the pure-neutral items, as the mixed-neutral items have not initially captured the call for resources therefore have a reduced post-perceptive response, which is reflected by the reduced Dm effect for mixed-neutral items in this time window.

The final stage to the two-step process is reflected in the ERP morphology of the later 800-1500 time window. This second step involves a slow wave, late positive potential (LPP), which is thought to reflect the maintenance and or manipulation of the visual pictorial stimuli in working memory, which in turn leads to successful encoding. This view is consistent with the literature, where slow waves are often thought to reflect sustained attentional engagement related to maintain and or manipulating information in working memory (Runchkin, Johnson & Friedman, 1988; Schupp et al., 2006; Olofsson et al., 2008). The exact reasons as to why this stimuli would need to be maintained and or manipulated in working memory is unknown, however research suggests it could linked with regulating an emotional reaction (Richards & Gross, 2000; Ochsner & Gross, 2005; Dillon, Ritchey, Johnson & LaBar, 2007) or perhaps as individuals try to create relational links between the stimuli to facilitate encoding (Talmi & McGarry, 2012).

This account supports the literature form eye-witness testimony that suggests the impairment of memory for irrelevant peripheral information might be caused by competition or attentional resources (Christianson & Loftus, 1987; Christianson, Loftus, Hoffman & Loftus, 1991; Christianson, 1992). The two-step theory is also consistent with the notion of distinctiveness and using intermixed lists. The initial stage of the model involves detecting relevant stimuli, which encompasses the negative or emotional items, as they are deemed task- relevant due to their evolutionary significance (Ohman, Flykt & Esteves, 2001; Ohman & Mineka, 2001) and the bodily responses they trigger that require emotion regulation (Ochsner & Gross, 2005). Therefore the negative items in pure-lists are deemed task-relevant, thus attended too and the negative items in the mixed-lists preferentially utilise the resources responsible for identifying task-relevant, ahead of the neutral items. After this initial stage of the process where the items are attended to as being task-relevant, they are then maintained and or manipulated in working memory, which aids successful encoding. In neutral pure-lists, although the items are not task-relevant due to evolutionary significance or emotion regulation, they would be appraised as task relevant, as individuals strive to create links of relatedness between the items, which is a key component of memory (Talmi & Moscovitch, 2004; Talmi, Luk, McGarry & Moscovitch, 2007; Talmi & McGarry, 2012). It is therefore likely that encoding neutral pure-list items required a high level of cognitive effort, in spite of the relatively modest recall performance (compared to negative pure-list items). Applying high level elaborative processing and higher cognitive effort has been shown to increase Dm activity and overall brain activity (Gray et al., 2005; Paller & Wagner, 2002; Otten et al., 2007; Caplan et al, 2009), which would explain the positive Dm effects observed for neutral pure-list items in this study. Therefore, in a similar manner to the way the negative items are encoded, once the initial stage of the process has begun and the neutral items are attended to as being task-relevant, they are then maintained and or manipulated in working memory, this aids their successful encoding, which is reflected in the behavioural recall performance.

The results surrounding the analysis of the data by a sub-sample of arousal, also supports the findings of the previous study (Watts et al., 2014), demonstrating the Dm effects observed for negative items were not the result of a confounding effect due to arousal; as there were significant Dm effects observed for both the low-arousal and the high-arousal conditions. Highly arousing items are known to cause more positive going Dm effects than less arousing or neutral items (Dolcos & Cabeza, 2002; Dolcos, LaBar & Cabeza, 2004), which explains why the high-arousal items had an overall more positive Dm effect than low-arousal items. Research has confirmed that this arousal effect is often extended to recall performance with a greater likelihood of highly arousing items being remembered than low-arousing or neutral items and this arousal-induced enhancement of memory is often attributed to activity of the amygdala (Bradley, Greenwald, Petry & Lang, 1992; Mather, 2007; Mather & Nesmith). However both this present study and the previous work (Watts et al., 2014) observed that there were no significant differences in the recall performance of low-arousal and neutral items in the pure-list condition. Given the literature on the arousal induced enhancement of memory and the fact that items in the low-arousal condition were different on both valence and arousal measures to the neutral items, this is a surprising finding. The previous study (Watts et al., 2014) also found the high-arousal items had a clear and significant Dm effect; however the low-arousal items did not (although this finding was not the case in this present investigation). Taken together the findings of the previous work and this present study, it suggests that the intermixed list of low-arousal and high-arousal items in the pure-list condition, may in some way be acting as a 'mixed-list'. That is to say, the equal level of recall performance between the low-arousal and neutral items in the pure-list condition may be due to the low-arousal item encoding being disrupted in pure-list condition as the processing resources are preferentially being applied to the high-arousal items. This suggests the low-arousal items are always facing a disadvantageous balance of attentional processing resources, with most of the working memory resources required to aid encoding being applied to high-arousal items, when the items are embedded together in pure-lists. Rather like the neutral item encoding is disrupted when they are embedded against the negative items, in the mixed-list condition. This finding would require future research, to disentangle whether the high and low-arousal items being embedded together in a pure-list are in fact acting as a pseudo-mixed-list condition.

Although these results do support the overall notion of a two step-process involving cognitive resources and working memory, there were some differences that need to be noted between this study and previous work. The results of this study showed there were significantly more negative images recalled in the mixed-list condition compared to the pure-list condition; whereas this effect was not found in the previous study. This result however is not surprising, as a similar result was observed in the initial behavioural pilot study (see 2.2 Behavioural pilot study, Chapter 2). This effect is likely to be linked to the effects of 'relative' versus 'absolute' distinctiveness, which are outlined in the introduction. To summarise, the negative items in the pure-list condition only have absolute distinctiveness, whereby the items can only be distinctive in their own right. Hence they are task relevant and capture attention resources due to their evolutionary significance (Ohman, Flykt & Esteves, 2001; Ohman & Mineka, 2001), the need for the emotions they illicit to be regulated (Ochsner & Gross, 2005) and the need to create relational links between the items (Talmi & Moscovitch, 2004; Talmi, Luk, McGarry & Moscovitch, 2007; Talmi & McGarry, 2012), as outlined above. Whereas in the mixed-list condition negative items also have absolute distinctiveness and all its related properties (as mentioned for pure-lists); but above and beyond absolute distinctiveness, items in the mixed-list also have relative distinctiveness properties. As the active conceptual framework has been manipulated by using an intermixed list, it makes the negative items relatively distinct against the background of neutral items (Schmidt, 1991; Schmidt & Saari, 2007; Talmi et al., 2007) and only relative distinctiveness is thought to benefit memory recall (Schmidt & Saari, 2007; Talmi, Luk et al., 2007); hence the increased recall performance of negative items in the mixed-list condition compared to the pure-list condition. This account also fits consistently with the two-step process outlined above. Distinctiveness is thought to be intimately related to attention (Talmi, 2012), in so much that the relative distinctiveness of negative items in the mixed-lists capture more attentional resources in the early stage of the process, which in turn leads to a greater maintenance in working memory in the second stage of the process. This culminates in more successfully encoded items from the negative mixed-list condition, compared to the negative pure-list condition. This interpretation is confirmed by a consistently larger Dm effect for negative items in the mixed-list condition, compared to the negative items in the pure-list condition. This reflects the greater attentional resources and working memory processes being applied to negative items in the mixed-list compared to the pure-list, due to the relative distinctiveness properties of negative items in the mixed-list but not the pure-list condition.

Further consideration must also be applied to the differences in the Dm effect for pure-list items in this study compared to the previous research. This present investigation shows the Dm effect for pure-list items appears to end around ~1100ms; whereas in the previous experiment (Watts et al., 2014), the LPP for pure-lists was sustained across the full 800-1500ms time window. As the literature on Dm effects shows, the Dm effects are known to move both spatially and temporally between studies (Paller & Wagner, 2002), therefore seeing differences between these two studies is not unexpected. The shorter Dm effect observed in this study again supports the notion that distinctiveness is playing a cognitive mediating role in the EEM. The relative distinctiveness that is known to aid memory encoding (Schmidt & Saari, 2007; Talmi, Luk et al., 2007) does not exist in pure-list items. The late LPP observed in the 800-1500 time window is thought to reflect the attentional processes of maintaining and manipulating information in working memory, which benefits successful encoding; this is in part driven due to the distinctiveness of items, more specifically the relative distinctiveness of items. As items in the pure-list condition do not have this added benefit, there would not be same level of maintenance and manipulation in working memory that was observed for negative mixed-list items. This is reflected by the shorter Dm effect for pure-list items in the 800-1500 time window, where we expect to see the later maintenance processes in working memory taking place. This effect is also reflected in the behavioural results for negative items, where there were less items recalled for negative pure-list, compared to the mixed –list condition.

In summary the above results suggest that the effects of distinctiveness are twofold. Firstly, the negative items in the mixed-list condition are both absolutely distinct and relatively distinctive, whereas the negative items in the pure-list are only absolutely distinct. This leads to more attentional resources being applied to the negative items in the mixed-list and through the two-step process outlined, leads to significantly more successfully encoded negative items in the mixed-list condition, compared to the pure-list condition. This is exemplified in both the behavioural and ERP results; by a significantly higher recall performance for negative items in the mixed-list condition, compared to the pure-list and a consistently larger Dm effect for negative mixed-lists compared to pure-lists. Secondly, the additional resources being applied to the negative items in the mixed-list condition (due to the relative distinctiveness nature of the items) disrupted the encoding of neutral mixed-list items as there were little or no resources left to assist the encoding of neutral items in mixed-lists. Again this is shown in both the reduction of neutral items recalled in the behavioural results and the cancellation of the Dm effect in an early and late time window in the ERP results.

The present findings present many avenues for future research. Firstly, more work needs to be done to establish how attention interacts with distinctiveness and the impact this relationship has upon the EEM. Perhaps following the behavioural work initiated by Talmi, Schimmack et al. (2007), Talmi (2012) and Pottage and Schaefer (2012) would be an interesting starting point, implementing divided attention paradigms or a paradigm to measure attentional cost. Secondly, this research has only investigated the effects of negatively valenced stimuli on EEM therefore further investigations would be needed to ascertain whether these conclusions can also be applied to positively valenced stimuli; the effect of valence on EEM is a topic of much debate (Kensinger & Schacter, 2008). Lastly, this study has presented some interesting findings in regards to arousal and pure-list conditions. This is definitely an area, which requires further research to establish if indeed the pure-list condition is behaving as a pseudo-mixed-list.

3.4.2 Individual Difference measures findings

An additional aim of this study was to investigate the role various individual difference measures can have upon the EEM and how these measures can interact with factor of distinctiveness. Overall, the individual difference measures investigated in this present study had low statistical power and did not present any robust findings to suggest meaningful interactions with the EEM. However there were some select areas of interest, which could warrant future research into individual differences and the impact they have on the EEM.

Firstly the results of the OSPAN test showed no significant effects on the behavioural results across any condition; suggesting working memory capacity (WMC) did not have a significant effect upon recall performance. Looking at the results in more detail, the mean recall performance showed a trend for participants with low WMC to have a consistently higher recall performance across all conditions. In addition, on the whole the ERP results supported the behavioural findings with no consistent effects of WMC correlating with any of the key conditions, in the key time windows, across the key scalp regions. These results do not support the hypothesis, which posited that individuals who had a higher WMC would be able to flexibly allocate attention and successfully encode both more negative and neutral items, than those with a lower WMC. Looking at the ERP results in more depth, did reveal a significant correlation in the early 200-400 time window between higher OSPAN scores (high WMC) and the Dm effect for mixed neutral items, specifically at posterior sites. This indicates that participants with a high WMC had a larger Dm effect for neutral items in the mixed-list condition, specifically at posterior sites; suggesting low WMC participants were more susceptible to the cancellation of the Dm effect for neutral mixed-list items in the early 200-400 time window. This finding does support the literature, whereby individuals with a higher WMC are able to more flexibly allocate attention (Bleckley et al., 2003) during the initial call for resources stage of the encoding process and attend to both the negative and neutral information. This additional cognitive effort would be reflected in an increase of Dm activity and an overall greater brain activity (Gray et al., 2005; Paller & Wagner, 2002; Otten et al., 2007; Caplan et al, 2009) for the higher WMC individuals. Whereas those with a low WMC, would not have the same ability to flexibly allocate attention, therefore the negative items in the mixed-list would preferentially gain the processing resources ahead of the neutral items; causing the cancellation of the Dm effect observed in this early time window. However, this advantage for higher WMC individuals is not followed through the middle or later time windows as the literature would suggest. The second stage to the encoding process outlined occurs in the later 800-1500 time window, where items are maintained and manipulated in working memory to facilitate encoding. However, WM does have a limit to the amount of information it can attend to at one time and maintain in a rapidly accessible state (Cowan, 2005), therefore it is not unlikely that WM would become overwhelmed if both the negative and neutral items it initially attended too were then expected to be maintained and manipulated. To put it in short, one cannot simply remember everything. Hence, even those with the highest WMC would lose the advantage found in the early stage of the encoding process, as the attentional resources in the second stage of the process have to be divided, as they cannot attend to such a large volume of stimuli in both the neutral and the negative items. At this second stage, it is likely the negative items then become preferentially maintained and manipulated in working memory, leading to their successful encoding. This interpretation is consistent with the behavioural findings, in that there was no difference between recall performance and WMC.

This explanation does not fully support the literature, which would expect there to be a clear difference in the recall performance between low and high WMC individuals, due to their ability to more flexibly allocate attention. Given the interpretation of the main findings places WM at the heart of the processes involved and the results of WMC upon recall performance presented in this study, future research into the effects of WM on the EEM is crucial. Elward et al. (2012) found that completing a cognitive demanding task, requiring cognitive control, caused a reduction in WMC that impacted performance on a subsequent task. Similarly Schmeichel (2007) demonstrated that tasks involving prior efforts of executive control temporarily undermine subsequent efforts at executive control. In this study, participants all completed the OSPAN task before moving onto the main task of remembering images; therefore it could have been the case that completing a cognitively demanding task of WMC first, had subsequently detrimental effects on recall performance in the main task. Given the behavioural results of this study are very similar to previous research (Watts et al., 2014), it is unlikely the OSPAN task had any disadvantageous effects upon the recall task; however it could be that the OSPAN task had an overall impact on WMC for the participants, which is why we found no significant effects of WMC upon recall. Future studies using measures of WMC should therefore consider when to administer initial WM tasks, if there is a subsequently cognitively demanding task to complete. Although the OSPAN task is known to correlate well with other measures of WMC (Unsworth et al., 2005), gaining a more robust measure of WMC above and beyond the OPSAN task could improve future studies. For example including a measure of fluid intelligence such as the Raven’s Advanced Progressive Matrices as other studies have done (Gray et al., 2005) in addition to a specific working memory task, such as the *N-back* task (Gray & Braver, 2002; Gray et al., 2005; Schaefer et al., 2006) could provide a better paradigm and improve the measure of WMC to directly verify the literature surrounding WMC and the EEM.

The next factor measured was the participants’ propensity to regulate their emotions via cognitive reappraisal and cognitive suppression techniques. The behavioural results found there was no significant difference between participants who were high-reappraisers or low-reappraisers and the recall performance. This was confirmed in the ERP results, with no significant correlations found between reappraisal scores and the Dm effect for any of the key conditions, in any of the key time windows, across ant of the key scalp regions. This finding is consistent with the hypothesis and the literature on emotion regulation, which suggests that one's use of reappraising negative or emotional items or events has no impact upon memory for said items (Richards & Gross, 2000; Gross, 2002; Shimmack & Hartmann, 1997; Egloff et al., 2006). The behavioural results for suppression also showed no significant differences between participants who were high-suppressors or low-suppressors, in recall performance across any of the key conditions. This again was reflected in the ERP results, with no significant correlations between suppression scores and the Dm effects for any condition. This result is not consistent with the hypothesis or the literature which proposes that using suppression to regulate one's emotions can impair memory for the event (Richards & Gross, 2000; Gross, 2002; Richards & Gross, 2006; Egloff et al., 2006; Dillon et al., 2007). These results could be down to the small sample sizes used in the analysis after the median split, to separate participants into low versus high reappraisers and suppressors and a lack of statistical power. As when we look closer at the correlations between suppression scores and the Dm effects, taking a 1-tailed significance score shows a marginal effect between suppression scores and posterior mixed-negative items. This indicates high suppression scores correlate with a smaller Dm effect for mixed negative items in posterior regions. This effect is consistent with the hypothesis that emotion regulation using suppression is cognitively demanding and can actually impair memory for negative items (Richards & Gross, 2006) and perhaps using a larger sample of participants would create the additional statistical power needed to make the effect stronger. However this effect in the ERP results for suppression scores is not translated into the behavioural results; as the mean recall performance for suppression shows a trend for high-suppressors to consistently have a higher recall performance across all conditions, compared to low-suppressors.

The confounding results presented by this study could be explained by the fact that participants were not explicitly instructed to use either emotion regulation technique during the experiment; whereas other studies in the literature often instruct participants to actively reappraise or suppress the emotional content of the stimuli (Dillon et al., 2007; Richards & Gross, 2006; Gross, 2002; Richards & Gross, 2000). By not explicitly instructing participants to utilise either emotion regulation technique means that this study was relying on the participants' own propensity to regulate their emotions. Emotion regulation is known to be a cognitively demanding exercise (Richards & Gross, 2006; Richards & Gross, 1999) and as participants knew they were completing a memory test, it could be that individuals were not regulating their emotional responses to the images, but instead using their cognitive resources to allocate attention and actively remember the images. Future research into the use of emotion regulation and the EEM should perhaps make use of explicit direction in the paradigms, and instruct participants to directly regulate their emotional responses or measure the extent to which they are implementing emotion regulation techniques, as other studies have done (Dillon et al., 2007; Richards & Gross, 2006; Gross, 2002; Richards & Gross, 2000). Further studies could also look at the relationship emotion regulation has with other cognitive factors which are known to influence the EEM. For example emotion regulation techniques are known to be influenced by an individuals' WMC (Schmeichel, Volokhov & Demaree, 2008); as WMC is a key component to the two-stage process used to explain the effects of distinctiveness, elucidating this interaction further would provide more evidence of the exact role both emotion regulation and WMC play in the EEM. In addition, Dillon et al. (2007) found that instructing participants to reappraise emotional stimuli and relate them more to themselves, actually enhanced memory for the emotional items. This finding is supported by the literature which suggests self-referential processing can improve recognition memory (Conway & Dewhurst, 1995). This finding is contrary to the emotion regulation literature, which suggests that reappraisal has no impact on memory (Richards & Gross, 2000; Gross, 2002; Richards & Gross, 2006; Egloff et al., 2006); therefore future research should look not only at the effect of suppression upon memory, but also the circumstances under which reappraisal can also affect memory.

The results of the Big Five Inventory revealed no significant correlations between any of the five dimensions measured and memory performance across the key conditions. The ERP findings reflected the behavioural results, showing no robust effects of any trait consistently in any key condition, in the three main time windows. A closer inspection of the ERP results presented a significant correlation negative correlation between the trait, Extraversion and the Dm mixed-negative condition, at both anterior and posterior sites, in the early 200-400 time window. This indicates that participants who scored low for Extraversion, had larger Dm mixed-negative waves in this early time window. This effect could be explained in terms of the factors known to affect the trait of Extraversion, which measures the score of Extraversion on a dimension ranging from Extraversion through to Introversion (John et al., 2008). The Extraversion dimension is known to have an effect on information processing and cognitive abilities such as working memory (Gray et al., 2005; Humphreys & Revelle, 1984); for example, Introverts are often rated as less efficient on cognitive tasks in comparison to Extraverts, however Introverts are able to compensate by expending additional effort on the task (Gray et al., 2005). Increased Dm activity has been associated with higher levels of cognitive effort (Paller & Wagner, 2002; Otten et al., 2007; Caplan et al, 2009), which would account for Introverts having a larger Dm effect for mixed-negative items, as they expend higher level of cognitive effort to attend to items in a mixed-list condition. Extraversion scores are also associated with positive effect (DeYoung, 2010), hence why participants who scored high for Extraversion, had smaller Dm effects for a negative image condition. In addition, Extraversion is associated with approach systems; therefore it is perhaps unsurprising that individuals scoring high for Extraversion would have a smaller Dm effect for mixed-negative images, as they are unlikely to apply approach behaviours to negative images. No significant correlations were found in the middle 400-800 time window; however there was a significant correlation between Extraversion and the Dm for pure-neutral condition, specifically at posterior regions. Again this was a negative correlation, meaning the individuals with lower scores on the Extraversion dimension had greater Dm activity in the pure-neutral condition. This finding could again reflect the greater level of cognitive effort that Introverts need to expend in order to compensate for their reduced efficiency in cognitive tasks (Gray et al., 2005). The pure-negative condition has the lowest level of arousal, of any of the conditions in the study and low arousal levels have been shown to have a detrimental effect on performance in complex cognitive tasks (Humphreys et al., 1984). Therefore the low arousal pure-neutral condition would be difficult to encode into memory, hence the additional effort required for Introverts in this condition, which is reflected in the greater Dm activity.

Summarising the findings of the Big Five Inventory, there were isolated significant ERP results (primarily located in the earlier time windows) however they did not translate into any differences in memory performance within the behavioural findings. This is consistent with the two-step process of distinctiveness and encoding outlined in the main findings of the Discussion (see section 3.4.1), whereby the first step primarily involves the selective allocation of attention resources to stimuli that is relevant to our goals and determines which stimuli require additional resources in order to process and encode. Whereas, the second step of the process is associated with the maintenance and manipulation of stimuli in working memory, which facilities the encoding of said stimuli. The ERP results presented here are associated with early time windows and the relevance detection process of the attentional resources, rather than the second stage that actually aids the encoding of the stimuli. This would explain why the effects found in the ERP data did not translate into memory recall differences in the behavioural data. Although these results do support the main findings somewhat, there were some aspects to these results that were unexpected. For example, though no formal hypotheses were formed regarding the Big Five personality dimensions and memory performance or ERP results, there were general expectations that the traits for Conscientiousness and Openness would correlate most strongly with memory performance and the subsequent ERP results. For example, it was expected that the Openness and Intellect dimension would have a relationship with recall performance, based on the strong association these traits have with intelligence and working memory (DeYoung et al., 2009). Likewise it was expected Conscientiousness would have significant associations with memory recall performance, due to the trait being related to individuals seeking goal-relevant information to hold in working memory (DeYoung, 2010).

Therefore it was unexpected not to achieve any significant relationships between these two key dimensions and our results. The null results of this study could be due to low statistical power due to the low number of participants used for this section of the analysis; four participants were excluded for being outliers, three of which were in these key trait conditions of Openness and conscientiousness. Consequently future studies should aim to more robustly test the dimensions of the Big Five Personality Inventory and how they interact with emotion and memory; specifically the traits of Openness and Conscientiousness, which most strongly correlate with measures of working memory. Research has shown the importance of personality upon cognition, however the work has been focused primarily on the Extraversion and Neuroticism personality traits, and their association with affective reactions (Gross, Sutton & Ketelaar, 1998) and working memory (Gray & Braver, 2002). Future studies should direct hypothesis towards the other less investigated personality dimensions and their interactions with cognitive abilities such as early working memory and attention effects, to empirically further research into personality cognitive neuroscience and truly elucidate the impact of personality on emotion and memory.

The final individual difference measure used was the BIS BAS scale. The results showed no significant correlations between the global BIS or global BAS scale and the recall performance across any of the key conditions. The ERP results also reflected this pattern and revealed no significant correlations between the global BIS and BAS scales and the Dm effects of any of the key conditions, across the main time windows. The BAS scale was broken down into three sub-factors of BAS-Drive, BAS-Fun seeking and BAS-Reward; these sub-factors also did not show any significant correlations between the recall performance of any condition. Inspecting the ERP results of the BAS sub-factors however, did reveal some isolated significant correlations. In an early time window, there was a significant positive correlation identified between BAS-Fun seeking and the Dm effect for the mixed-negative condition; whereby a higher Extraversion score on the BAS-Fun seeking sub factor was associated with greater Dm activity in the mixed-negative condition. BAS-Fun seeking is associated with the willingness to seek out and approach rewarding experiences (Carver & White, 1994). Therefore the larger Dm effect for mixed-negative items would be due to the greater level of cognitive effort (Paller & Wagner, 2002; Otten et al., 2007; Caplan et al, 2009) the higher scoring BAS individuals were applying to the mixed-negative items as they are more motivated to perform well in difficult cognitive tasks (DeYoung et al., 2009). However, this evidence is in contrast to the patterns of activity which surrounded Extraversion, as measured by the Big Five Inventory. This evidence is also contrary to the literature which posits that BAS measures and Extraversion are generally associated with positive emotions and approach behaviour (DeYoung et al., 2009; DeYoung, 2010). The middle 400-800 time window revealed a further two significant correlations; the first a positive correlation between Bas-Fun seeking and Dm activity for pure-neutral items and the second was a negative correlation between BAS-Drive and the pure-neutral condition. The contradiction of two BAS scores both negatively and positively correlating with pure-neutral items is difficult to interpret. Similar to the previous time window, higher BAS-Fun seeking scores could reflect an increased motivation to perform on difficult cognitive tasks. The pure-neutral condition is a low-arousal condition and low arousal has been associated with lower performance (Humphreys et al., 1984). Thus the pure-neutral condition is one of the more difficult conditions and requires more motivation to perform; hence the greater Dm activity for this condition. In a similar way, the BAS-Drive scale is thought to reflect the persistent pursuit of desired goals (Carver & White, 1994). The pure-neutral condition does not benefit from the same level of goal-relevance as the other conditions (See 3.4.1 Discussion, Chapter 3); therefore participants who score high on the BAS-Drive scale and are motivated to pursue goals, would not be able to make as much use of this trait in the pure-neutral condition. Hence, they would not exert the subsequent cognitive effort required to make use of pursuing goal-relevant items, as much as they perhaps would do in other conditions that have a higher level of goal-relevance. This was reflected lower levels of Dm activity in the pure-neutral condition, when participants had scored high on the Drive scale. The final 800-1500 time window continued the patterns established in the earlier time window and revealed a significant negative correlation between the BAS-Drive scale and the Dm effect for pure-neutral items, at both anterior and posterior regions. This would support again the notion that high BAS-Drive score individuals would usually make use of pursing goals and the reduced goal-relevance of the pure-neutral items means these individuals cannot utilise this trait as much as in other conditions. This was exemplified by lower the lower levels of cognitive effort exerted by high BAS-Drive scorers in this condition and the subsequent lower Dm activity recorded.

Similarly to the effects of the Big Five Personality Inventory, the effects observed in the ERP activity of the BAS sub-factors did not translate into recall performance in the behavioural results. The timing of the ERP effects are consistent with the two-step process of distinctiveness and encoding outlined in the main findings (see 3.4.1 Main findings, Chapter 3). The early effects of BAS-Fun seeking would reflect the reward aspect of the BAS scale, as individuals are motivated to perform well in the task (DeYoung, 2010), they allocate attention to the motivationally-relevant stimuli (Schupp et al., 2006; Olofsson et al., 2008), which is the first step of the process. However, effects of BAS-Fun seeking are not associated with later time windows where working memory interactions are thought to aid encoding; hence, there are no significant correlations between memory performance and BAS-Fun seeking. The BAS-Drive effects are significant in middle to late time windows, which would be consistent with research suggesting post-perceptive attentional responses to stimuli, involving more controlled processes. This would fit with the explanation that BAS-Drive reflects the persistent pursuit of desired goals (Carver & White, 1994) and utilising the goal-relevance of the stimuli, which would be a cognitively controlled process. However, there were no significant effects of BAS-Drive in the early time window which is unexpected; as the early time window is primarily associated with allocating attention on the basis of identifying which stimuli are goal-relevant. In addition, given the effects of BAS-Drive are significant in later time windows where interactions are thought to aid memory encoding, it is surprising that BAS-Drive effect does influence memory encoding. Although there were no formal hypothesis surrounding the BIS and BAS scale measures and memory performance, there were some general expectations. For example, it was expected that individuals who scored high on the BIS scale (more neurotic), would be generally more anxious and unable to perform cognitively demanding tasks, to the same ability as high BAS (Extraverts) scoring individuals (Gray et al., 2002; Gray et al., 2005). Neuroticism is associated with responses to aversive stimuli (DeYoung et al., 2009) but surprisingly, despite the use of negative stimuli there were no effects involving BIS scores at the behavioural or the ERP level. Future work will be needed to fully understand the effects identified and to further the field of personality neuroscience as a whole. Similar to the Big Five traits of personality, research around the BIS and BAS scales and cognition have focused mainly on the impact they have on working memory (Lieberman, 200; Lieberman & Rosenthal, 2001; Gray & Braver, 2002; Gray et al., 2005). However future studies should aim to go beyond working memory to other cognitive factors such as attention, to empirically investigate the impact of personality on emotion and memory and contribute to the field of personality neuroscience in general. Combining research into personality traits, beyond Extraversion and Neuroticism, can produced complimentary theories as to the neurobiology to personality traits. For example it has been suggested that Neuroticism, Agreeableness and Conscientiousness can be combined to form a higher-order factor of Stability, related to the neurotransmitter serotonin; whereas, Extraversion, Openness and Intellect can be combined to form Plasticity and are related to the dopamine (DeYoung et al., 2009). Understanding the neurobiology and the neurotransmitters involved in personality traits will only serve to help elucidate how they impact more complex interaction, such as emotion and memory.

In summary, the results of the individual difference measures here present interesting avenues for future research. Although the OSPAN task did not reveal any significant effects of WMC and memory performance, future research should use additional methods to test WMC and implement paradigm which directly test the capacity of WM. Working memory is a crucial part of the explanation to distinctiveness and the EEM, therefore it is imperative to understand how WM can interact with emotion and memory. The tests of Emotion Regulation in this study did not find significant differences between the constructs of reappraisal or suppression on memory performance; however we did explicitly instruct participants to regulate their emotions and given the interaction emotion regulation can have upon working memory, work needs to be done to understand the impact emotion regulation can have upon the EEM. The final tests of personality dimensions (as identified by the Big Five Inventory and the BIS BAS scales), did not reveal robust relationships with memory performance or strong effects upon the ERP results. However the exploration this study presents leaves interesting avenues for future research in the field of personality neuroscience, to better understand the impact personality traits can have upon the EEM.

3.4.3 Conclusions

This study supported the findings of the work presented in Chapter 2 and argues in favour that the effects of distinctiveness upon the EEM are twofold, via a two-step encoding process. Distinctiveness can enhance the memory for negative items when they are presented in a mixed- list, due to the crucial factor of relative distinctiveness that items in a mixed-list condition hold. Distinctiveness also reduces the memory for neutral items presented in a mixed-list condition, as the attention processing resources are preferentially allocated to the negative items, at the expense of encoding the neutral items. Both of these processes occur through a two-step process; the first step involves an initial call for resources whereby task-relevant stimuli are attended too and additional processing resources are prepared to be allocated to relevant stimuli. In the second stage, the attentional processing resources are now mobilised and applied to the relevant stimuli, which are then maintained and or manipulated in working memory, aiding their encoding success.

Chapter 4: Using a true pure-list paradigm to investigate the effects of arousal at encoding in the absence of cognitive mediating factors, upon the immediate EEM

4.1 Chapter Overview

This work aims to uncover the effects that arousal can have upon the immediate EEM, in the absence of key cognitive mediating factors. Furthermore, this investigation aims to address the possibility that when items are presented in a pure-list condition, but have intermixed levels of arousal (e.g. mixed high and low-arousal images), they can act as a pseudo-mixed list condition; with the higher arousing items capturing the majority of processing resources and being successfully encoded, at the expense of lower arousing items. The study involved encoding images in three different conditions (pure high-arousal, pure low-arousal and pure-neutral) followed by an immediate free recall memory test. The findings revealed two key points; firstly, the results showed that arousal alone is not sufficient to enhance behavioural recall rates in the immediate EEM, despite observing robust effects of arousal in the ERP results. In addition, the behavioural recall rates of high and low-arousal conditions observed the same level of recall rates; suggesting that in previous pure-list conditions that presented intermixed levels of arousal, may have indeed been acting as a pseudo-mixed list condition. The implications of these findings are discussed in more detail below.

4.1.1 Introduction

Memories for emotionally arousing stimuli are typically remembered better, with an increased accuracy (LaBar and Cabeza, 2006) and detail (Schaefer & Philipot, 2005) compared to neutral stimuli. This phenomenon is more commonly referred to as emotionally enhanced memory (EEM; Talmi, Schimmack, Paterson & Moscovitch, 2007) and has been widely examined in the literature using pictures (Bradley, Greenwald, Petry & Lang, 1992), words (Kleinsmith & Kaplan, 1963), taboo words (Schmidt & Saari, 2007; Labar & Phelps, 1998) and narratives (Laney, Campbell, Heur & Reisberg, 2004; Cahill & McGaugh, 1995). Despite extensive research into the cognitive neuroscience of emotion and memory (see Labar & Cabeza, 2006 for review), the exact mechanisms involved are still widely unknown.

The EEM is often explained in term of the modulation hypothesis (McGaugh, 2004), which proposes that the amygdala is critically involved in forming memories which are emotionally arousing. The modulation model suggests that the baso-lateral complex of the amygdala (BLA) selectively mediates the consolidation of long-term emotionally arousing memories, by influencing interactions involving adrenal stress hormones and several classes of neurotransmitters (McGaugh, 2004; Labar & Cabeza, 2006). The modulation hypothesis has extensive support from many animal studies. Early studies demonstrated how electrically stimulating the amygdala of rats, impaired later memory performance in a trained task; suggesting the amygdala plays an important role in memory consolidation (Goddard, 1964). Later animal studies then found that memory performance could in fact be impaired or enhanced, depending on the intensity of the stimulation (Gold, Hankins, Edwards, Chester & McGaugh, 1975). This work suggests that the memory effects being modulated by the amygdala are not solely impairing effects and provides strong evidence to suggest that the modulation process involves projections from the amygdala to other brain regions (McGaugh, 2004). Evidence has long existed suggesting that the adrenal stress hormones released due to emotionally arousing stimulus, can aid the consolidation of memories of training experiences in animal studies (Gold & McGaugh, 1975). Recent studies using intra-amygdala infusions of drugs have isolated the baso-lateral amygdala's involvement in memory consolidation across a range of different training paradigms (see McGaugh, 2004 for review). Evidence now suggests the baso-lateral amygdala is essential to mediating and selectively modulating the memory effects of adrenal stress hormones and a range of neurotransmitters (McGaugh 2000; McGaugh & Roozendal, 2002). These findings from animal studies are consistent with evidence from human studies, which indicate that stress hormones and the amygdala play a critical role in the modulation of emotional memories (McGaugh, 2004). Emotionally arousing stimuli that cause the release of stress hormones modulate the effects of memory, and these effects are selectively mediated by activation of the amygdala, which in turn also influences projections to other brain regions, such as the medial temporal lobe, which are critical for forming long-term memories (McGaugh, 2004; Dolcos, LaBar & Cabeza, 2004a).

High levels of arousal are often implicated as the driving force behind the consolidation process of emotional memories and the modulation hypothesis, with specific hormonal mechanisms and neural networks responsible for emotional items (McGaugh, 2004; McGaugh, 2000; McGaugh & Roozendaal, 2002; Cahill & McGaugh, 1998; Kensinger & Schacter, 2008). The dimension of arousal is a measurement of perceived emotional intensity and is quantified across a range from calm through to excited (Bradley & Lang, 1994). However it is worth noting, evidence from animal studies suggests that under extreme levels of stress, arousal can impair memory (Kim, Lee, Han & Packard, 2001). The enhanced memory for emotional items is thought to have an adaptive function; whereby emotionally positive or negative items engage additional resources from cognitive factors such as attention, which in turn aid encoding and allow an individual to remember or avoid items relevant to ones goals (Lazarus 1991; LeDoux, 1995).

The modulation hypothesis therefore offers a robust explanation as to how emotional stimuli are consolidated into long-term memory and it puts the arousing nature of emotional stimuli at the forefront of this theory. Although the modulation hypothesis offers an encompassing explanation as to the consolidation and storage of long-term emotionally arousing memories, as Talmi (2013) points out, it offers little explanation as to the encoding and immediate effects of EEM that are well documented in the literature (Talmi, Schimmack et al., 2007; Talmi, Luk, McGarry & Moscovitch, 2007; Talmi, Anderson, Riggs Caplan & Moscovitch, 2008; Schaefer, Pottage & Rickart, 2011; Pottage & Schaefer, 2012; Watts, Buratto, Brotherhood, Barnacle, Schaefer, 2014). The modulation hypothesis and consolidation process is known to take hours with effects only notable after a long-term retention interval (Cahill & McGaugh, 1998). However, as mentioned the effects of emotion on memory can be noted immediately after testing (Talmi, 2012; Hamann, 2001), hence the consolidation process and modulation hypothesis only offers a partial explanation of the effects of emotion upon memory. The interactions between emotion and memory at encoding happen independently of the consolidation process proposed by the modulation hypothesis, which suggests a key distinction between the immediate effects of emotion upon memory at encoding and the effects of emotion on long-term memory.

Despite arousal playing a key role in the delayed effects of emotion on memory, little research has established the effects that arousal can play on the immediate EEM. Instead the effects of emotion on memory noted immediately at encoding are often explained in terms of a cognitive mediating mechanism (Talmi, Schimmack et al., 2007); whereby cognitive factor such as attention, distinctiveness and relatedness are affected by emotional stimuli at encoding, resulting in the mnemonic advantage of emotional stimuli over neutral stimuli. Behavioural studies from the literature have implicated a wide range of potential cognitive mediating factors (Talmi, 2012). Emotional items are known to have priority over processing resources, which can improve their encoding in memory (Kensinger & Schacter, 2008). This can be explained due to the increased visual attention allocated to emotional items at encoding, which can improve memory (Pottage & Schaefer, 2012; Talmi, Schimmack et al., 2007); or due the relative distinctiveness of emotional items compared to neutral items, which in turn causes emotional items to capture more attention, hence improving memory for emotional stimuli (Watts et al., 2014; Talmi, Luk et al., 2007). Emotional items are also thought to engage a deeper meaning based processing. Items which are processed with a greater semantic or cognitive analysis are known to have a deeper level of encoding (Craik &

Lockhart, 1972). Emotional items are said to naturally have more semantic relatedness, hence why they have a mnemonic memory advantage (Talmi, 2012).

These cognitive factors have all been shown to play a role in the immediate emotion enhancement of memory and offers support for the cognitive mediating hypothesis. Despite the strong evidence presented to support the cognitive account of immediate EEM, as mentioned above, the important role that emotional arousal plays in the long-term modulation of emotional memories warrants further investigation into the potential role that arousal can play on immediate emotional memory; above and beyond the influence of cognitive mediating factors. Studies have shown both arousal and valence to be important to the immediate effects of EEM; with an amygdala-hippocampal network implicated for arousal effects and a prefrontal-hippocampal network suggested for valence effects (Kensinger & Corkin, 2004). The literature proposes both valence and arousal influence the cognitive mediating factors responsible for the immediate effects associated with EEM; however arousal is thought to play a more important role in initialising the cognitive factor of attention (Talmi, Schimmack et al., 2007; Kensinger & Corkin, 2004).

As such, this study aims to manipulate the arousal levels of images lists to specifically investigate how arousal can influence the immediate EEM, when other enhancing cognitive factors are not allowed to play a role. To address this aim, this present study will implement an immediate free recall memory test based on the encoding of three pure-list conditions: a pure high-arousal image condition, a pure low-arousal image condition and a pure-neutral image condition. The images were separated into true pure-list conditions of separated by arousal, as this eliminates the confounding cognitive factor of distinctiveness and the subsequent attentional resources that are involved in distinctiveness processing (see 1.7.1 Distinctiveness, Chapter 1; 3.1.1 Introduction, Chapter 3; Talmi, Luk et al., 2007; Watts et al., 2014). Removing some of cognitive mediating factors that are known to influence EEM will isolate the factor of arousal and allow a more detailed examination of the effects of arousal at encoding.

Using this unique true pure-list paradigm also allows us to address an outstanding question that was raised in the previous chapter (see 3.4 Discussion, Chapter 3). The previous study (see Chapter 3) utilised a pure-list condition, however the pure negative list of images contained intermixed levels of arousal (intermixed high and low-arousal images). The recall results of using this pure-list design revealed a surprising result; the recall rates for the low-arousal images was the same as the recall rates for the neutral images (see 3.3.1.2 Results, Chapter 3). Furthermore, there was also a significant difference between the recall rates of the high-arousal and low-arousal condition. Although this effect is not entirely unexpected, taking the two results together offers the potential for an interesting interpretation. We suggested that when items are presented in a pure-list negative condition, but with intermixed levels of arousal (intermixed high and low-arousal images), the high-arousal items in that pure-list may be preferentially capturing the processing resources and achieving enhanced encoding at the expense of low-arousal items. This would behave much in the same way of a mixed-list condition; whereby the negative items in a mixed list condition have been shown to preferentially capture processing resources and significantly reduce the availability of encoding resources to neutral items (Watts et al., 2014). Hence, we have termed this interpretation the 'pseudo-mixed list'; as the pure-list condition with intermixed arousal levels may be reacting in a similar way to the classic mixed-list conditions (see Figure 4.1). As such, the design of this present study will allow us to investigate this interpretation further. This study will present true pure-list conditions that have homogenous arousal levels. Therefore, if the recall rates in this study are similar to those of the previous studies (see Chapter 2 and 3) then we can assume that the previous pure-lists were not acting as a pseudo-mixed list condition. However, if the recall rate of the low-arousal items in this study are significantly higher than the neutral condition and more comparable to that of the high-arousal condition, this would suggest that in previous studies using intermixed pure-list designs, the high-arousal items have been preferentially capturing the processing resources at the expense of the low-arousal items and thus behaving as a 'pseudo-mixed' list condition.

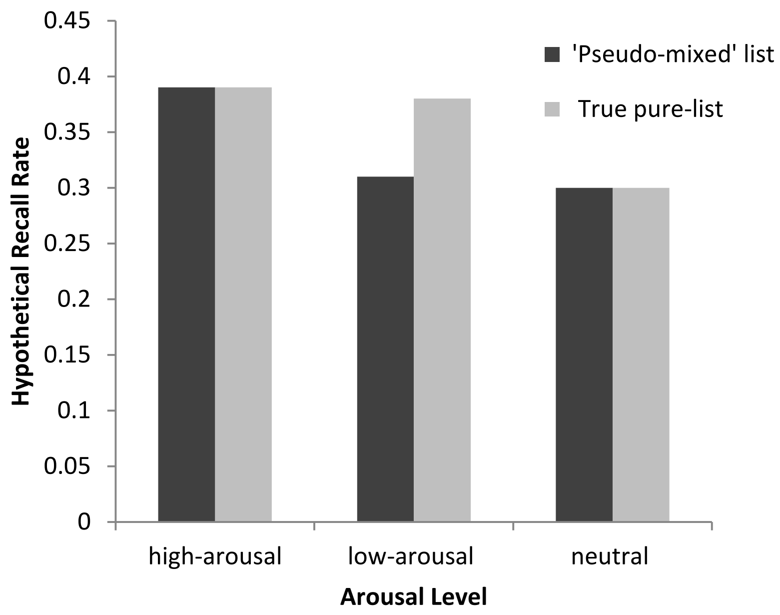

Figure 4.1: Hypothetical bar graphs to demonstrate the differences in recall rates between previous negative pure-list conditions ('pseudo-mixed' lists) and the true pure-list conditions of this present study.

To examine precisely the mechanisms underlying the both the effects of arousal on the immediate EEM and the potential that previous pure-list conditions were behaving like a ‘pseudo-mixed’ list, we used EEG and event-related potential (ERP) methods to obtain the ‘Dm effect’. The Dm effect represents the differential neural activity based on memory (Paller & Wagner, 2002), which is a well-known neural index reflecting the successful encoding of items in memory. The encoding related activity for items which were successfully encoded is separated from items that were subsequently forgotten, and a contrast created; this is known as the Dm effect (Paller & Wagner, 2002). This technique has been implemented across numerous studies (Paller, Kutas & Mayes, 1987; Mangels, Picton & Criak, 2001; Rugg, Otten & Henson, 2002; Duarte, Ranganath, Winward, Hayward & Knight, 2004; Otten, Quayle, Akram, Ditewig & Rugg, 2006; Blumenfeld and Ranganath, 2006; Bridger and Wilding, 2010), with many of the studies reporting the consistent finding of a larger positivity for remembered items compared to forgotten items (Paller & Wagner, 2002) and a larger positivity for negative items compared to neutral items (Dolcos & Cabeza, 2002). Evidence from the literature demonstrates that the Dm effects are known to move both spatially and temporally, suggesting that the Dm effects reflect several different levels of encoding processes (Paller & Wagner, 2002; Friedman & Johnson, 2000; Otten, Sveen & Quayle, 2007). Despite this, there are many Dm effects frequently reported in the literature relating to emotional stimuli. Dm effects relating to affective picture have been reported at early time windows (pre-400ms) and are thought to reflect the stimulus driving properties of affective images due to their motivational and evolutionary significance (Schupp, Flaisch, Stockburger & Junghofer, 2006; Olofsson, Nordin, Sequeira, Polich, 2008; Walker, O’Connor & Schaefer, 2011). These findings are consistent with other Dm effects often reported in the literature during divided attention tasks at similar time windows, which are thought to reflect the initial capture of attentional and perceptual resources (Duarte et al, 2004; Otten, Sveen & Quayle, 2007). A common effect reported in the literature of affective images is the late positive potential (LPP). This effect is often observed ~400ms onwards and is thought to reflect the post-perceptive attentional resources, which were called in response to the affective stimuli; the LPP is consistently reported as more positive going for negative items compared to neutral (Codispoti, Ferrari & Bradley, 2007; Olofsson et al., 2008). These LPP findings correspond with effects reported in the literature in a similar time window, across both fronto-central (Friedman & Trott, 2000; Otten et al., 2007) and centro-parietal (Fabiani, Karis & Donchin, 1990) sites, which are thought to reflect attentional engagement and enhanced elaboration (Paller & Wagner, 2002). One final important Dm effect relating to affective pictures to note is the late LPP. This effect is observed in a later (post-800ms) time window and is thought to represent the manipulation of information in working memory, which aids the long-term encoding of affective items (Leutgeb, Schafer & Schienle, 2009; Schienle , Kochel & Leutgeb, 2011; Olofsson et al., 2008; Schupp et al., 2006). These late LPP effects corroborate with other findings reported in the literature observing Dm effects in a similar time window, primarily at frontal and posterior sites, which are said to reflect the activity of working memory resources modulating successful encoding (Mangels et al., 2001; Otten & Rugg, 2001; Caplan, Glaholt & McIntosh 2009; Kim, Vallesi, Picton & Tulving, 2009). Limited studies have utilised the Dm effect in an EEG study using a pure list paradigm design, as outlined by this present study. Sommer and colleagues however conducted an fMRI study which removed the cognitive mediating factors and found increased activity in the amygdala and hippocampus, providing support for the effects of arousal at both immediate EEM and the long-term modulation hypothesis (Sommer, Glascher, Steffen, Christian, 2008). This study will further these findings by utilising EEG recording and the Dm effect to isolate the temporal dynamics of the effects of arousal at encoding and the immediate EEM.

This study will therefore present three true pure-list conditions of images (high-arousal, low-arousal and neutral) to be encoded and subjected to an immediate memory test. The first aim of the study is to investigate the role that arousal plays upon immediate EEM. It is expected if arousal plays a significant effect, there will be significant differences in the behavioural recall rate according to arousal level; with high-arousal condition having the highest level of recall, followed by the low-arousal condition and then the neutral condition. It is expected that if arousal plays a significant role, these relationships will also be reflected in the ERP data; with the largest Dm effects observed for high-arousal items, followed by low-arousal items then neutral items. The second aim of the study is to investigate the notion that previous negative pure-list conditions that used intermixed levels of high and low arousal items, were acting as a ‘pseudo-mixed’ list condition. It is expected that if behavioural recall rates are the same as those observed in the previous studies then the condition was not behaving as a pseudo-mixed list. However, if the low-arousal condition recall rates are comparable to the high-arousal condition and significantly higher than the neutral condition then it is likely the previous pure-lists could have been behaving as a ‘pseudo-mixed’ list condition.

4.1.2 Aims

- To investigate the specific impact of arousal on the immediate EEM, in the absence of important cognitive mediating factors.
- If arousal plays a significant role at encoding, we expect to observe a significant impact on recall; with the high-arousal condition having the highest level of recall, followed by the low-arousal condition, then the neutral condition.

- We expect to find a significant effect of arousal upon the Dm effect, with the key Dm effects expected to be primarily found in the time windows outlined above; reflecting the additional processing resources allocated to items of higher arousal levels as a result of the effects of arousal at encoding
- To investigate the possibility that using intermixed levels of arousal in a negative pure-list condition, created a ‘pseudo-mixed’ list condition

4.2 Methods

4.2.1 Participants

Twenty right-handed adults (6 Males) with a mean age of 21 years (SD = 3.05 years) from Durham University and the surrounding area, with no history of psychiatric or neurological conditions, took part in this study in exchange for £15 cash or course credit. Due to the negative nature of the stimuli used any participants who scored above 21 on the Beck's Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) or those who scored above 50 on State Trait Anxiety Inventory (Speilberger, Gorsuch & Lushene, 1970) were excluded from the participating in the study. All participants gave informed consent and the study was approved by the local ethics committee. During the analysis it was found that one participant had a corrupt EEG recording and had to be excluded from the analysis. This left a final sample of 19 participants (5 males) with a mean age of 21.05 years (SD = 3.60).

4.2.2 Stimuli and Design

This study used realistic colour images showing emotionally negative or neutral scenes, obtained from the International Affective Picture System (IAPS) (Bradley & Lang, 1994; Lang, Bradley & Cuthbert, 2005). In addition, similar to previous studies (Yamasaki, LaBar & McCarthy 2002) images were added to the IAPS data set from Google Image™ in order to match the emotional and neutral images for key non-emotional dimensions (e.g. presence of humans, animals and objects; see appendix G). In total 360 images were shown to the participants across all picture sets (278 IAPS images and 82 Google Image ™); with all images resized to 455 x 342 pixel format and displayed centrally at 1024 x 768 pixels, on a 40cm x 30cm Samsung SyncMaster computer screen (TCO'03 Displays, MagicBright).

All the images used in this study were previously rated for valence and arousal, by a sample of British students (Schaefer et al., 2011; Pottage & Schaefer, 2012) using a 5-point version of the Self-Assessment Manikin (SAM): whereby Valence was rated as 1 = negative, 5 = positive; Arousal was rated as 1 = low, 5 = high arousal (Bradley & Lang, 1994). Using these ratings, the images were divided into subsets of emotionally negative and neutral images: 240 emotionally negative images (mean valence = 1.94, SD = 0.27; mean arousal = 3.28, SD = 0.29) and 120 neutral images (mean valence = 3.16, SD = 0.27; mean arousal = 1.84, SD = 0.39). Analysis revealed that the image subsets were significantly different from each other for both valence and arousal ($p < 0.001$).

The negative picture set was further divided into high and low arousal sub-sets using a median split, in order to create three sets of images: 120 high-arousal images (mean valence = 1.68 , SD = 0.32;

mean arousal = 3.69, SD = 0.34); 120 low-arousal images (mean valence = 2.20, SD = 0.23; mean arousal = 2.86, SD = 0.25) and 120 neutral images. Analysis showed that all three image subsets were significantly different on both valence and arousal scores (*p< 0.001)*.

The three sub-sets of images (high-arousal, low-arousal and neutral) were each divided into 5 pure lists; creating 5 pure lists of high-arousal images, 5 pure lists of low-arousal images and 5 pure lists of neutral images; creating 15 list presentations in total. Each list contained 24 images and all lists were balanced for key non-emotional features, such as the presence of humans, animals and objects. All 15 lists were presented to every participant and the lists were grouped by arousal type, so all high-arousal lists were presented together, all low-arousal lists were presented together and all neutral lists were presented together. Lists were presented according to valence, therefore half of the participants saw the negative images first (high-arousal and low-arousal lists) and the other half of participants saw the neutral images first. The order of presenting either the high-arousal images or the low-arousal images first (within the negative image section) was counterbalanced across participants and the order of images within each list was also randomised.

4.2.3 Procedure

All participants viewed the images, sat in a chair approximately 70cm from a 19” CRT screen on which the stimuli were displayed. The images were displayed on screen using E-Prime 2.0 (Psychology Software Tolls, Pittsburgh, PA) and the accuracy of the synchronisation between the onset of the visual stimuli on the screen and the trigger received by the EEG system, was measured using BlackBox Toolkit (BlackBox Toolkit Ltd, York, UK) (see 2.2.3 Methods, Chapter 2.). Each trial started with a fixation (small black asterix) displayed centrally on a white screen for 600ms, followed by a blank white screen for 100ms. The image was then displayed centrally on a white background for 1500ms and it was given 100% width and height. After each image had been displayed, participants were presented with a 5-point version of the SAM (1 = positive and 5 = negative) whereby they had to rate the valence of the previous image, using the 1-5 numbers marked out on a serial response box (Psychology Software Tools™). Participants could take as long as need to make the valence rating and once they had responded there was a blank white screen presented for 800ms, before the onset on the next trial (See figure 4.2).

At the end of each block of 24 trails (24 image presentations), participants were required to perform a series of simple arithmetic questions for 90 seconds, to minimise the possibility of any rehearsal of the images between the encoding and the recall phase. The arithmetic questions consisted of simple mathematical problems, involving addition, subtraction, multiplication and division, which were all printed on paper for participants to answer by hand. Participants were encouraged to solve as accurately as possible as many questions as they could within the timed 90 second period. After the 90 seconds of arithmetic questions, participants were instructed to recall (for up to 5 minutes) as many of the images they could remember from the previous block they had just seen. Participants were required to write down a brief description on the paper provided, of any of the images they could remember, using the following instructions:

"*You now have around 5 minutes to recall as many of the images that you have just seen. Please be exact and succinct in your descriptions, using only 3 or 4 main words for each picture, avoiding long sentences. If there are any ambiguous descriptions the experimenter will ask you to clarify at the end of the study. If you are unsure of any descriptions of the images, please do include them too, even if you feel you are just guessing.*"

Although participants did have up to 5 minutes to recall the images, most participants did not need the full 5 minutes. We used a liberal criterion as previous studies have done, as this has been shown to increase the amount of accurate information retrieved during memory tests, so as to maximise recall in our study (Pottage & Schaefer, 2012; Wright, Gabbert, Memon & London,2008). All participants were well practised and performed 10 practice trials following the above format (displaying images similar to what the experiment would present) and were given the opportunity to ask any questions, in order to familiarise themselves with the experimental procedure before beginning the recorded trails.

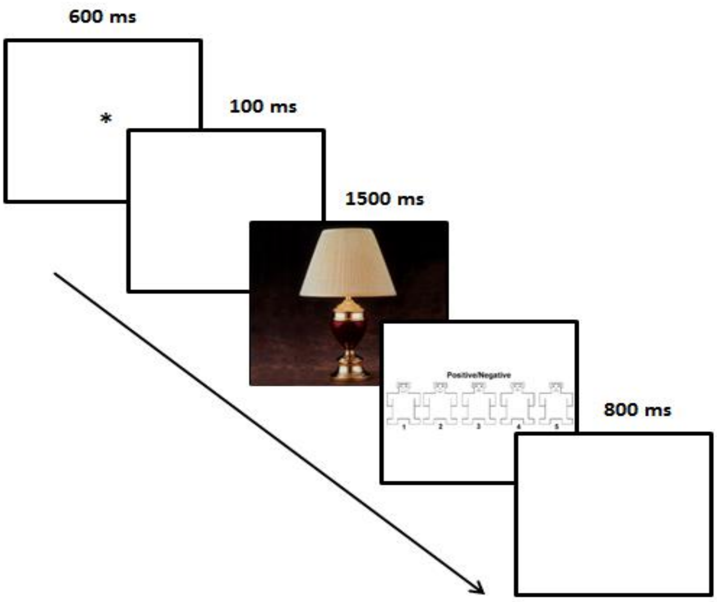

Figure 4.2: Schematic representation of the experimental trial procedure.

4.2.4 Memory Coding

The free recall descriptions made by each participant were independently recoded by two coders, which follow methods established by previous research (Bradley, Greenwald, Petry & Lang, 1992; Talmi et al., 2007; Pottage & Schaefer, 2012). To prevent the possibility of false positives (false memories being encoded as true memories) being made, only descriptions that could be identified as belonging to one particular image and could be differentiated from other images in the block were recorded as true memories. Following methods used by previous studies (Pottage & Schaefer, 2012; Watts et al., 2014) any description that was too vague to definitely allow concrete identification were deemed as false memories and discounted. As with previous studies, recoding the images was a straightforward process, which was reflected in the high agreement between encoders (97%). Any disagreements that did occur between encoders were resolved by taking a conservative interpretation of the methodology outlined above.

4.2 5 Electrophysiological data recording and processing

The scalp electrophysiological activity (EEG) was recorded using a 64-channel cap (Waveguard, ANT Inc., Enschede, Netherlands) at a rate of 512 Hz (DC-138 Hz bandwidth) and with an impedance < 20 kΩ. EEG data was recorded using an average reference and then digitally converted to a linked mastoids reference. The EEG data was analysed using the ERP module of BESA 5.3 (MEGIS software GmbH, Grafelfing, Germany). All data were filtered offline (0.03-30 Hz), corrected for eye movements (Berg and Scherg, 1994), segmented into epochs between 100 ms before and 1500 ms after stimulus onset and baseline corrected. For each channel, any epochs that had a difference between the maximum and minimum voltage amplitudes exceeding 120 µV or a maximum difference between two adjacent voltage points above 75 µV (after eye-movement artifact correction) were rejected.

ERP waveforms were created by averaging EEG data for remembered trials (items that were successfully recalled) and forgotten trials (items that were not recalled) separately for the lists of high-arousal, low-arousal and neutral images, resulting in six trial types: high-arousal-remembered, high-arousal-forgotten, low-arousal-remembered, low-arousal-forgotten, neutral-remembered and neutral-forgotten. Consistent with the criterion followed in previous memory studies (Watts et al., 2014; Azimian-Faridani and Wilding, 2006; Kim, Vallesl, Picton & Tulving, 2009; Gruber and Otten, 2010; Galli, Wolpe & Otten, 2011; Padovani, Koenig, Eckstein & Perrig, 2013), participants that recorded fewer than 12 artifact-free trials in any of the six key conditions were excluded from the analysis. There were six conditions in total (high-arousal-remembered, high-arousal-forgotten, low-arousal-remembered, low-arousal-forgotten, neutral-remembered and neutral-forgotten) and the mean numbers of artifact-free trials per condition were: 44.42, 71.47, 42.12, 74.79, 35.21, and 72.68.

4.2.6 ERP data analysis

4.2.7 Selection of time windows and scalp locations

Based on a careful visual inspection of the data and the literature outlined in the introduction (see 4.1, Introduction) mean amplitudes were extracted from three main time windows: 200-400, 400-800 and 800-1500ms. These time windows are both consistent with our previous ERP studies which examined pure-list conditions (see Chapter 2 and 3) and with the Dm effects observed in the literature. The early 200-400ms time window covers the temporal regions usually associated with emotional images and the stimulus driven properties attributed to emotional images, due to their evolutionary and motivational significance (Schupp et al., 2006, Olofsson et al., 2008, Walker et al, 2011). These effects tend to reflect early attentional and perceptual resources, which have been also been noted in the literature in similar time epochs (Duarte et al., 2004, Otten et al., 2007). The middle 400-800ms time window covers the Dm effects outlined in the literature that tend to begin

~400ms (Friedman & Trott, 2000; Otten at al., 2001; Fabiaani et al., 1990) as well as specifically targeting the late positive potential (LPP), a component known to be responsive to affective images (Codispoti, De Cesarel & Ferrari, 2012). These effects are thought to be associated with the post-perceptive attentional resources, which are often observed in this time window (Codispoti et al., 2007; Olofsson et al., 2008). The final 800-1500ms time window relates to the 'late LPP' or sustained slow waves; this is thought to reflect items being manipulated in working memory (Leutgeb, Schafer, Schienle, 2009; Schienle, Kochel & Leutgeb, 2011; Olofsson et al., 2008; Schupp et al., 2006), which can modulate working memory processes (Mangels et al., 2001; Otten & Rugg 2001; Caplan et al., 2009; Kim et al., 2009).

The findings of the previous chapters (see 2.4 Results and 3.3 Results, Chapters 2 and 3), which used ERP recordings and a pure- list condition manipulation were used to guide the selection of scalp regions for this study as no other ERP study to our knowledge has used a pure-list manipulation using images. The literature specifically outlines regions such as the left amygdala as significantly modulating the encoding of arousal items (Kensinger & Corkin, 2004) and the left prefrontal cortex being associated with lower arousal items (Kensinger & corking, 2004; LaBar & Cabeza, 2006). Therefore scalp regions were selected to fully encompass both anterior and posterior regions, spanning across left, midline and right electrode sites: left-anterior (F7, F5, F3, FT7, FC5, FC3), midline-anterior (F1, Fz, F2, FC1, FCz, FC2), right-anterior (F8, F6, F4, FT8, FC6, FC4); left-posterior (P7, P5, P3, TP7, CP5, CP3), midline-posterior (P1, P2, Pz, CP1, CP2, CPz) and right-posterior (P8, P6, P4, TP8, CP6, CP4). The data was averaged for single electrodes inside each ROI (Watts, et al., 2014; Schaefer et al., 2011; Walker et al., 2011; Curran et al., 2006), in order to address familywise error in dense arrays of electrodes (Oken & Chiappa, 1986).

4.2.8 Statistical analysis

A repeated measures ANOVA was computed on the mean amplitude data from each of the time windows (200-400, 400-800, 800-1500) using the following factors: Memory (Remembered vs Forgotten items), Arousal (high vs low vs neutral items), A-P (Anterior vs Posterior electrode sites) and Laterality (Left, Midline or Right electrode sites). Considering the hypothesis of the study, effects and interactions involving the factors of Memory and Arousal were preferentially targeted. Additionally, it was also decided to follow up any key interaction involving the factor of A-P as previous studies have observed important effects across posterior electrode sites (see 2.5 and 3.4 Discussion, Chapters 2 and 3). It was expected that there would be a significant main effects of both Arousal and Memory; with high-arousal items and remembered items having larger positive going waveforms than low-arousal or neutral and forgotten items. It was also expected that there would be significant interactions involving Arousal and Memory, with high-arousal items having larger Dm effects than low-arousal and neutral items. Any significant effects involving the factor of Memory were followed up with subsidiary analysis down to the level of Remembered vs Forgotten pairwise comparisons. For all analyses, partial eta-squares or Cohen's *d* statistics were reported to provide estimates of effect-size and Greenhouse-Geisser corrections were used, with corrected p values reported where relevant.

4.3 Results

4.3.1 Behavioural Results

4.3.1.1 Recall

An initial inspection of the behavioural results suggested there were no obvious differences in the amount of images recalled between the neutral, low-arousal or high-arousal conditions (see Figure 4.3). Computing a one way repeated measures ANOVA using the factor of Arousal on the recall rates revealed as expected a non-significant effect of Arousal [$F(2,36) = 1.944$, $p = .158$, $\eta p^2 = .097$].

Overall these results are not consistent with the expectations of the hypothesis, which suggested if arousal plays a significant role in the immediate EEM there would be significant differences in the recall rates between all three arousal conditions. In contrast however, these results offer support for the hypothesis surrounding the 'pseudo-mixed' lists; whereby there was no significant difference between the recall rates of the high-arousal and low-arousal condition. This finding suggests that when the high-arousal and low-arousal items were mixed in the pure-list condition as in previous studies (see Chapters 2 and 3), there were significant differences found in the recall rates between the high and low arousal conditions, suggesting those conditions may have been acting as a pseudo-mixed list; enhancing the memory of high-arousal items at the expense of low-arousal items. Hence, when the items were presented in true pure-lists with similar arousal levels, as in this present study, there were no differences between the recall rate of the high and low-arousal condition.

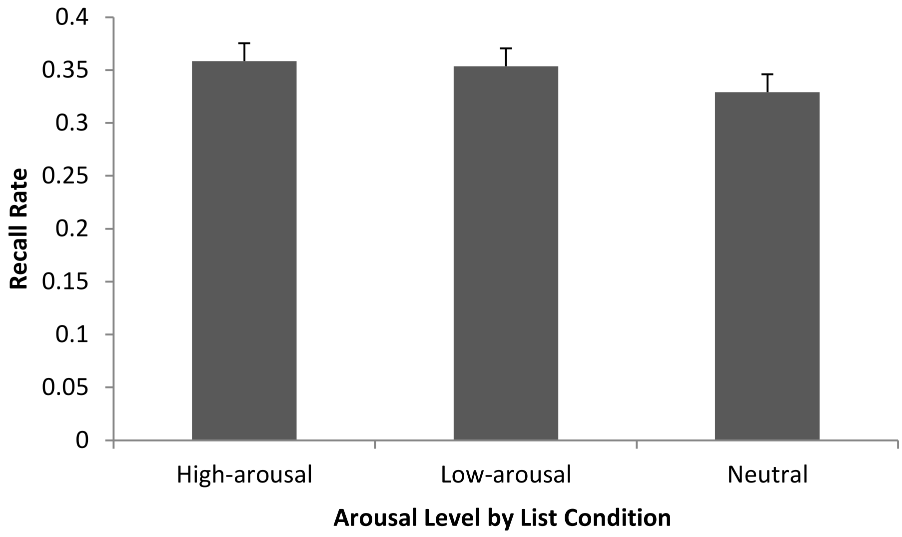

Figure 4.3: Mean recall rate by Arousal condition. Error bars represent standard error of the mean.

4.3.1.2 Reaction time and SAM results

Analysis of the SAM ratings recorded during the study revealed a significant main effect of List Condition [$F(1, 21) = 62.323$, $p < .001$, $\eta p^2 = .776$, $\varepsilon = .57$], indicating as expected that the valence ratings between the three conditions were significantly different. Bonferroni pairwise comparisons showed a significant difference between all three levels of arousal (all *ps* < .001) with the high-arousal condition having the highest mean SAM valence rating (mean rating = 4.27, SD = .33) followed by the low-arousal condition (mean rating = 3.79, SD = .39) then the neutral condition (mean rating = 2.92, SD = .36). Analysis on the response time for the ratings made on the SAM during the experiment were also computed and revealed a non-significant effect of reaction time (RT) [F(2,36 = .327, p =.723, $\eta p^2 = .018$]. This indicates there were no differences in the time taken to make a response on the SAM between any of the three main arousal conditions (high-arousal RT mean = 772.2ms, SD = 338.97ms; low-arousal RT mean = 804.57ms, SD = 266.17ms; neutral RT mean = 785.16ms, SD = 331.49ms).

4.3.2 ERP Results

A visual inspection of the data shows a robust overall Dm effect for high-arousal and low-arousal items, with a pronounced differentiation between the waveforms for subsequently remembered and subsequently forgotten items (see figure 4.4). This strong Dm effect starts around ~200ms and generally extends to the end of the recorded epoch at 1500ms. Although the Dm effect appears strong overall for negative items, it is worth noting that the Dm effect for the neutral condition appears to be reduced across most of the recorded epoch. A closer examination of the neutral condition waveforms suggests that there is a moderate Dm effect starting around ~300ms, particularly around frontal and central electrode sites; however this effect is not sustained over the full epoch, as the Dm effect comes to an end around ~800ms. There is a marked reduction in the Dm effect in an early (pre ~300ms) and late (post ~800ms) time window; with the Dm effect post ~800ms even appearing to be reversed, specifically over posterior electrode sites.

The statistical analysis will further this initial visual inspection of the data and examine more closely the temporal and spatial dynamics of the Dm effects for the high-arousal and low-arousal condition. It will also explore if the noted cancellation of the Dm effect in the neutral condition is reliable.

200-400

An Arousal X Memory X A-P X Laterality within subjects ANOVA revealed as expected, a significant main effect of Arousal [$F(2, 36) = 9.264$, $p < .001$, $\eta p^2 = .34$] and a main effect of Memory [$F(1, 18) = 8.386$, $p < .01$, $\eta p^2 = .318$]. Bonferroni pairwise comparisons revealed significantly more positive going waveforms for high-arousal items compared to low-arousal (ps = .007) and neutral (*ps* = .011) items. These results indicate more positive going waveforms for higher arousing conditions compared to lower arousing conditions and an overall larger positivity for subsequently remembered items compared to subsequently forgotten items. A main expectation of this study was to find effects and interactions involving the factors of Arousal and Memory, however there was no Arousal X Memory interaction in this time window (*ps* = .282). The ANOVA instead revealed two other significant interactions involving these factors; Memory X Laterality [$F(2, 36) = 5.548$, $p < .01$, $\eta p^2 = .236$] and Arousal X Laterality [$F(4, 72) = 4.573$, $p < .01$, $\eta p^2 = .203$] . There was also an interaction, with a moderate to large effect size involving all of these factors, Arousal X Memory X Laterality [$F(4, 72) = 2.205$, $p = .077$, $\eta p^2 = .109$]. Based on the expectations of this study these effects were targeted and the data was separated by Arousal to elucidate these interactions. A subsidiary Memory X Laterality ANOVA was computed, for the three levels of Arousal (high-arousal, low-arousal and neutral) separately.

This analysis on the low-arousal condition revealed a significant main effect of Memory [$F(1, 18) = 7.811$, $p = .012$, $\eta p^2 = .303$], reflecting the overall main effect of memory observed above. The effects of Memory here were found to be localised particularly to Midline (*ps* = .007) and Right (*ps* = .029) electrode sites. Similarly the analysis on the high-arousal condition also revealed a significant main effect of Memory [$F(1, 18) = 6.228$, $p = .023$, $\eta p^2 = .257$] and a significant Memory X Laterality interaction [$F(2, 36) = 3.75$, $p = .040$, $\eta p^2 = .172$, ε = .87]. It was found the effects of Memory were driven by significant effects of Memory across Midline (*ps* = .009) and Right (*ps* = .012) electrode sites. The same analysis conducted on the neutral condition however did not reveal a significant main effect of Memory ($F < 1$).

Although these was no significant Arousal X Memory interaction in this time window, these results indicate there is a main effect of Arousal, with high-arousal items having significantly more positive going waveforms than low-arousal and neutral items, across all electrode sites. The Dm effect is also strong for high-arousal items, particularly across Midline and Right electrode sites. Similarly, the low-arousal condition showed Dm effects across Midline and Right electrode sites. However there were no significant effects involving the neutral condition, across any of the electrode sites. These results support the initial visual inspection of the data and confirm an early cancelation of the Dm effect for neutral items.

400-800

Computing the same Arousal X Memory X A-P X Laterality 4-way general ANOVA again revealed significant main effects of Arousal [$F(1, 25) = 19.946$, $p < .001$, $\eta p^2 = .526$, ε = .69], Memory [$F(1, 18) = 12.732$, $p = .002$, $\eta p^2 = .414$] and A-P [$F(1, 18) = 78.205$, $p < .001$, $\eta p^2 = .813$]. Similar to the previous time window, bonferroni pairwise comparisons revealed high-arousal items were significantly more positive going than low-arousal (*ps* = .002) and neutral (*ps* < .001) items. In addition, the pairwise comparisons also showed low-arousal items were significantly more positive going than neutral (*ps* = .006) items. As with the previous time window, this analysis preferentially targeted effects of Arousal and Memory. As such the ANOVA confirmed a marginally significant interaction between Arousal X Memory [$F(2, 36) = 3.136$, $p = .056$, $\eta p^2 = .148$]. However in addition, the ANOVA in this time window also revealed significant interactions involving Arousal X A-P [$F(2, 36) = 6.656$, $p < .01$, $\eta p^2 = .270$], Arousal X Laterality [$F(4,72) = 9.267$, $p < .001$, $\eta p^2 = .34$] and a Memory X Laterality interaction [$F(2, 36) = 7.95$, $p < .001$, $\eta p^2 = .306$]. Given the specific effects achieved at certain lateralities in the 200-400ms time window, it was decided to follow the factor of Laterality up in this analysis. Also as mentioned in the Methods (4.2.8, Methods, Chapter 4) the effects achieved specifically at posterior electrode sites have been very influential in previous studies, therefore it was decided to also follow up how A-P is interacting with Arousal and Memory.

Therefore to elucidate the results, the data was first separated by Arousal and a subsidiary Memory X A-P X Laterality ANOVA computed, for each of the three Arousal levels (high-arousal, low-arousal and neutral) separately. Similarly to the first time window (200-400), the ANOVA revealed significant main effects of Memory for the high-arousal [$F(1, 18) = 17.807$, $p < .001$, $\eta p^2 = .497$] and low-arousal [$F(1, 18) = 21.266$, $p < .001$, $\eta p^2 = .542$] condition, but not for the neutral condition ($F < 1$). There was a significant interaction of A-P X Laterality across all three Arousal levels (high-arousal, $ps = .053$, $\eta p^2 = .234$; low-arousal, $ps = .011$, $\eta p^2 = .223$; neutral, $ps = .05$, $\eta p^2 = .153$). There was also an interaction between Memory X Laterality for high-arousal [$F(2, 36) = 5.489$, $p = .008$, $\eta p^2 = .234$] and low-arousal [$F(2, 36) = 4.592$, $p = .017$, $\eta p^2 = .203$] items.

To break down these interactions a subsidiary analysis computed a one factor Memory ANOVA separately for high and low arousal items. The results revealed the effects for high-arousal items were driven by significant main effects of Memory across anterior sites, specifically at Midline, ($ps = .004$) and Right ($ps = .006$) electrode sites; and posterior regions across all three Lateralities, Left ($ps = .002$), Midline ($ps < .001$) and Right ($ps = .002$) electrode sites. Similarly the analysis for low-arousal items revealed the effects were driven by significant effects of Memory across all Lateralities at anterior regions (Left, $ps = .015$; Midline, $ps < .002$; Right, $ps = .035$ electrode sites) and all posterior regions (Left, $ps = .005$; Midline, $ps = .001$; Right, $ps = .004$ electrode sites).

These findings support the results of the previous early (200-400) time window and demonstrate a significant effect of Arousal; whereby high-arousal items consistently have larger more positive going waveforms than low-arousal and neutral items and low-arousal items waveforms are more positive going than neutral items. There were reliable effects of Memory, with Dm effects reported for high-arousal and low-arousal items, across both anterior and posterior sites. However, there were no Memory effects surrounding the neutral items, again confirming a significant reduction in the Dm effect across the neutral condition.

800-1500

Analysis using the same general Arousal X Memory X A-P X Laterality revealed as expected a significant main effect of Arousal [$F(1, 24) = 14.733$, $p < .001$, $\eta p^2 = .450$, $\varepsilon = .67$]. Bonferroni pairwise comparisons confirmed significantly more positive going waveforms for high-arousal items compared to both low-arousal ($ps = .022$) and neutral ($ps = .002$) items. Similar to the previous time window (400-800) the pairwise comparisons also confirmed that the low-arousal waveforms were significantly more positive going than the neutral condition (*ps* = .006). The general ANOVA however unexpectedly revealed there was no significant main effect of Memory in this later time window (*ps* = .216, ηp^2 = .084). Again focusing the analysis on the key factors revealed a significant interaction involving Arousal X Memory X Laterality [$F(4, 72) = 2.62$, $p < .05$, ηp^2 = .127].

To break down this interaction as in the 200-400ms time window, a subsidiary Memory X Laterality ANOVA was computed for each level of arousal separately. As in the previous time windows, the neutral condition did not observe a main effect of Memory (*ps* = .486), but instead showed a reverse Dm effect with the waveforms for the subsequently forgotten items being more positive going than the waveforms for subsequently remembered items. However, the same analysis on the high and low arousal items revealed a significant main effect of Memory for both the high-arousal [$F(1, 18)$ = 9.14, p = .007, ηp^2 = .337] and low-arousal condition [$F(1, 18)$ = 5.199, p = .035, ηp^2 = .224]. Although there were no significant interactions found involving Laterality, given the specific effects observed at certain Lateralities in the previous time windows it was decided to find out specifically where the Dm effects were strongest. The results for the high-arousal condition confirmed the Dm effect was significant across all three Lateralities (Left, *ps* = .012; Midline, *ps* = .004; Right, *ps* = .018 electrode sites). The results for the low-arousal items however found, similar to the early 200-400ms time window the Dm effect was only significant across Midline (*ps* =.017) and Right (*ps* = .029) electrode sites.

These results support the earlier findings and demonstrate a significant main effect of Arousal in the later time window. Whereby high-arousal items have consistently more positive going waveforms compared to low-arousal and neutral items; and low-arousal items have consistently more positive going waveforms compared to neutral items. However there was not the main effect of Memory as previously seen in the analysis, which was a surprising finding. However when the interactions were broken down it was found that the lack of a main effect of Memory was driven by the strongly reduced Dm effect observed in the neutral condition. This corresponds with the initial visual inspection of the data, which suggested that the Dm effect in the neutral condition was significantly reduced and in some places even reversed (See Figure 4.4). There were however main effects of Memory observed in both the high-arousal and low-arousal conditions.

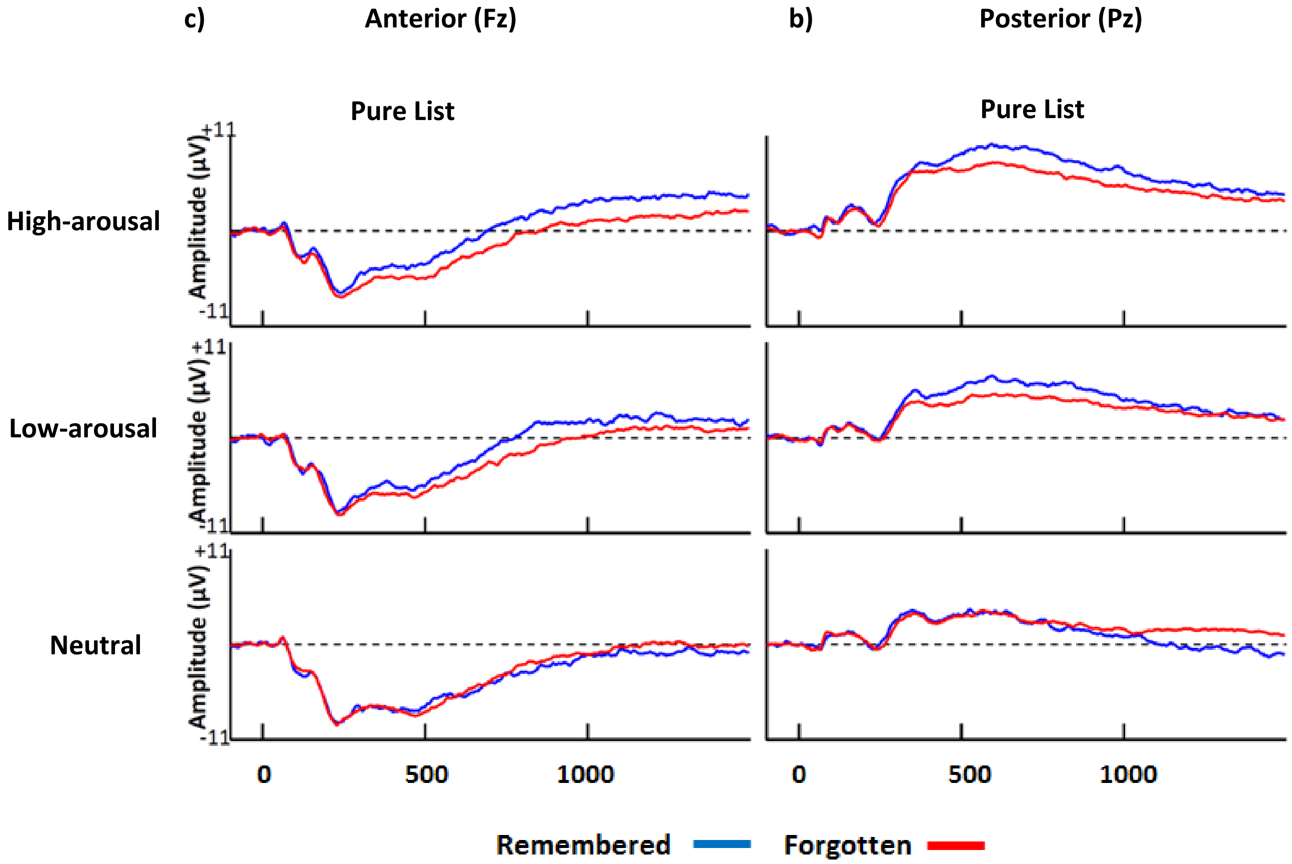

Figure 4.4: a) ERP waveforms plotted on electrode Fz for encoding-related activity separated according to subsequent memory (Remembered Vs. Forgotten items) and Arousal level (high-arousal Vs. low-arousal Vs. neutral items). Amplitude in microvolts (µV) is on the *y* axis and time in milliseconds is on the *x* axis. b) ERP waveforms plotted on electrode Pz for encoding-related activity separated according to subsequent memory (Remembered Vs. Forgotten items) and Arousal level (high-arousal Vs. low-arousal Vs. neutral items). Amplitude in microvolts (µV) is on the *y* axis and time in milliseconds is on the *x* axis.

In summary these results suggest a robust effect of arousal upon the recorded waveforms; with high-arousal items being the most positive, followed by low-arousal then neutral items. There were strong Dm effects observed in the high-arousal condition, globally across both anterior and posterior sites, in all three time windows. The low-arousal condition also showed robust Dm effects, however these were primarily driven by effects at Midline and Right Lateralities. These effects support the hypothesis of a robust Dm effect for high-arousal and low-arousal items across the whole recorded epoch and provide evidence to suggest Arousal plays a key role in EEM. However, it does provide interesting findings, as these results at times appear to be localised to Midline and Right Lateralities (specifically for low-arousal items), a result not previously found (Watts et al., 2014). The neutral condition however, did not demonstrate any reliable Dm effects, across any region or time window.

This is a surprising finding, as previous research found reliable Dm effects in pure-list conditions (Watts et al., 2014).

4.4 Discussion

The results overall do not reflect that arousal had a significant impact upon the immediate EEM. The recall rates do not show an overall main effect of arousal and as such, it suggests that arousal alone was not sufficient to enhance the immediate effects of emotion upon memory. In contrast however, the ERP results did observe a significant main effect of arousal with more positive going waveforms for the high-arousal condition, followed by the low-arousal condition, then the neutral condition. Supporting the findings of previous research and the expectations of this study, there were strong Dm effects for high-arousal and low-arousal items (see Results 3.3, Chapter 3). However unlike the previous work (Watts et al., 2014), the present study did not find any Dm effects for the pure neutral condition.

The first aim of this study was to investigate the role that arousal plays on the immediate EEM, in the absence of key cognitive mediating factors, which are known to enhance memory. Examining closely the exact impact of arousal at encoding within the behavioural results shows that there were no statistically reliable results to confirm a significant main effect of arousal. The results of the present study demonstrated that the recall rates between high and low-arousal items were comparable. These results are in contrast with the linear relationship of arousal levels on memory performance shown in the previous study (Watts, et al. 2014) and what was expected from this study, had arousal played a significant role at encoding. This suggests that in the absence of other memory enhancing cognitive mediating factors (such as distinctiveness), arousal alone is not sufficient to enhance memory immediately after encoding. We can be confident that distinctiveness was not able to play a memory enhancing role due to the true pure-list design of the study. Likewise, as reaction times on the SAM were consistent across all three conditions, it suggests that neither condition was selectively capturing more attention than the other. This evidence provides support for the cognitive account of EEM (Talmi & McGarry, 2012; Talmi, 2013), which posits that the immediate EEM is a result of cognitive factors such as attention and distinctiveness, change the cognitive attributes of emotional items, which in turn causes their mnemonic memory advantage (Talmi, Shimmack, et al. 2007). In this present study the true pure-list design means the usual cognitive factors that emotional items rely on are absent and the only difference between the conditions is the arousal level of the images. The unexpected finding of the recall rates between high and low-arousal items being comparable, suggests that higher arousal levels alone are not enough to enhance memory, immediately after encoding.

Despite the recall rates confirming there was no significant effect of Arousal levels upon the immediate EEM, the results do reveal a mnemonic advantage for negative items over neutral items.

Combining the low-arousal and high-arousal conditions into one negative recall condition, a post hoc 1 tailed t-test between the recall rates of negative compared to neutral items revealed there were significantly more negative items recalled compared to neutral items [$t(19) = 1.95$, $p = .034$, $d = .34$]. This finding is consistent with the literature, which often reports a mnemonic memory advantage for negative or positive items over neutral items; even in the absence of cognitive mediating factors, when a pure-list paradigm was used (Talmi, Luk, et al., 2007; Mather & Nesmith, 2008; Monnier & Syssau, 20008; Brown & Schaefer, 2010; Majerus & D'Argembeau, 2011). This mnemonic advantage for emotional items is often explained in terms of the organisation and relatedness of emotional items. Talmi and colleagues posit that emotional items tend to have an inherent degree of organisation (which is known to benefit memory; Hunt & McDaniel, 1993) and relatedness, with natural thematic relationships aiding the encoding of emotional items above that of neutral items (Talmi, Luk, et al. 2007). It has been shown that when neutral items are controlled for relatedness to the same level as emotional items, the memory advantage for emotional items disappears and recall becomes comparable between emotional and neutral items (Talmi & Moscovitch, 2004; Talmi, Luk, et al. 2007; Talmi & McGarry, 2012; Talmi, 2013).

The ERP results however do not reflect exactly the trend obtained in the behavioural results. The ERP results observe robust Dm effects across all time windows for both high-arousal and low-arousal items. Although the Dm effects for low-arousal items are strong, the Dm effects observed for high-arousal items are consistently more positive going with an overall larger Dm effect. Likewise, the Dm effect for low-arousal items is consistently significantly more positive going and larger than the waveforms of the neutral condition. This confirms the linear relationship of arousal levels upon encoding that we expected to see, if arousal influences the immediate EEM. However this linear effect did not translate into the behavioural memory recall results and despite a consistently larger Dm effect for high-arousal compared to low-arousal items, recall rates between the two conditions were comparable, as outlined above. These results suggest a clear effect of arousal upon Dm waveforms at encoding. Arousal is known to influence ERP components across a large time window with effects ranging from 200-1000ms (Olofsson, et al. 2008; Olofsson & Polich, 2007; Codispoti, et al. 2007), which are consistent with the continual effects of arousal observed across the 200-1500ms time window of this study. The effects associated with arousing stimuli and thought to be automatic and can even occur when processing resources are diverted to a secondary task (Kensinger & Corkin, 2004). This automatic effect of arousal is thought to reflect the capture of attention and the subsequent allocation of processing resources, as items which as highly arousing have intrinsic motivational relevance (i.e. is something deemed a threat to me?); hence it is important they preferentially capture the processes resources and are remembered better (Bradley, et al. 1992; Olofsson et al., 2008). Research has shown items that are more highly-arousing have more positive going waveforms and are subsequently remembered better (Dolcos & Cabeza, 2002). This is partially consistent with our data, which show items that are more highly arousing have more positive going waveforms; however, these more positive Dm effects have no impact upon memory recall. It is well believed that arousal modulates the long-term consolidation of emotional items and that the level of activity recorded at the amygdala at encoding, correlates highly with the subsequent recall after a period of delay (McGaugh, 2004;Phelps, 2004; Sommer et al., 2008). However, Hamann and colleagues have reported that amygdala activity for arousing stimuli recorded at encoding, can predict subsequent memory performance even after short delays (Hamann & Mao, 2002; Hamann, 2001). It has also been observed that unpleasant stimuli elicit stronger emotion effects compared to pleasant stimuli (Ochsner, 2000; Crawford & Cacioppo, 2002); this it is suggested, could be as a result of the rapid processing of negative stimuli by the amygdala (LeDoux, 1995; Olofsson et al., 2008). Kensinger and Corkin (2004) reported that activation in the amygdala correlated with subsequent memory performance for arousing items but not for non-arousing items.

Together this evidence lends itself to the possibility that amygdala activation can affect the encoding of arousing stimuli; correlating with memory recall after immediate delays as well as the modulation of long-term consolidation. That is to say, highly arousing items may be processed differently during encoding, which aids their long-term consolidation (Hamann, 2001). This theory would be consistent with the data of the present study. The linear increase of neural activity based on arousal does not reflect subsequent memory recall, as there is not a linear relationship to the behavioural recall data. The linear increase in neutral activity surrounding arousal levels could instead be reflecting the initial stages of the long-term modulation and consolidation of arousing stimuli in memory. Whereby, as the arousal of a stimulus increases so too does the automatic capture of resources (Bradley et al., 1992) as reflected in the greater neural activity for highly arousing items; which in turn stimulates the process of consolidation of highly arousing items via the amygdala and the projections to other brain regions (McGaugh, 2004; Phelps, 2004).

This theory is further supported by some of the localised findings in the ERP data along both a longitudinal and lateralised axis presented in this current investigation. Evidence from the literature strongly implies the amygdala plays a crucial role in attending to items at encoding (Phelps, 2004), which over time leads to the consolidation of the stimuli so that arousing items persist for a long time in memory (LaBar & Phelps, 1998). This role of the amygdala at encoding is thought be a rapid and automatic response (Phelps, 2004; Dolan & Vuilleumier, 2003); so much so, that amygdala activation at encoding can still predict subsequent memory for arousing stimuli, even when a secondary task which taps into attentional resources is used (Kensinger & Corkin, 2004). It has been shown that arousing material produces more positive going waveforms (Cuthbert, Schupp, Bradley, Birbaumer & Lang, 2000), which is consistent with the linear positivity of the waveforms shown in this study, as arousal increases. Activity at anterior regions is often implicated as predicting subsequent memory of emotional items, as the amygdala modulates the consolidating activity of the medial temporal lobe (MTL) and anterior parahippocampal areas (Dolcos, Labar & Cabeza, 2004a; Labar & Cabeza, 2006). More specifically, it is activity in the prefrontal cortex (PFC) that shows sensitivity to arousal and Dm activity in the PFC is usually greater for arousing stimuli (Dolcos, LaBar & Cabeza, 2004b; Kensinger & Corkin, 2004). The amygdala has also been shown to modulate activity at encoding in the orbitofrontal cortex and facilitate sensory detail (Kensinger, 2009). This activity reported in anterior regions, the PFC and orbitofrontal cortex would correspond with the consistent global Dm activity recorded for both high and low-arousal items, with strong effects observed across anterior regions in this study. Moreover, studies have demonstrated that the right PFC is activated during evaluation of negative stimuli (Dolcos et al., 2004b) and the right amygdala activity during encoding predicted subsequent memory performance for negative film clips (Cahill et al., 1996). This evidence would support the findings of our study that observed early Dm effects for arousing items primarily over medial and right electrode sites. Evidence from the literature shows the amygdala has projections as far reaching as the fusiform gyrus, which are thought to reflect the higher visual processing related to arousing items (Vuilleumier, Richardson, Armony, Driver & Dolan, 2004). These interpretations would correspond with the Dm activity recorded in this study, specifically the significant Dm effects observed at posterior sites, in the 400-800ms time window.

Future studies are needed to fully establish if these localised areas of activity are indeed a reflection of the amygdala and its reciprocal projections, as part of the wider consolidation process of arousing stimuli. However, the overall data does suggest that there is specific activity relating to arousing items surround the amygdala and the efferent projections to different brain regions, at encoding (Hamann, 2001). When stimuli are presented in a paradigm that allows mediating cognitive enhancing factors to play a role, the cognitive factors can act in tandem with the activity in the amygdala to immediately enhance memory for emotional stimuli (Hamann & Mao, 2002). However, amygdala activity recorded alone at encoding is not enough to predict subsequent memory for emotional items, immediately after test (Hamann, Ely, Grafton & Kilts, 1999; Tabert et al., 2001). This supports the notion that although amygdala activity can be recorded at encoding, the modulation and consolidation of emotional memories takes a period of time before the effects are noted in a subsequent memory test (McGaugh, 2004). To confirm that this recorded activity in some way reflects the very initial stages of the modulation and consolidation processes, future studies could implement this paradigm, but test memory recall both after an immediate interval and a delay; this would ascertain whether the increased activity at encoding for arousing items, correlates with subsequent recall after a delay.

Taken together, this evidence supports both the cognitive account and the modulation theory of EEM. The findings to support the cognitive account of immediate EEM demonstrate that when cognitive factors (such as distinctiveness) are unable to play a role at encoding, there is no memory advantage; hence a higher level of arousal alone is unable to immediately enhance memory. The only memory factor present in the absence of cognitive factors, is the mnemonic advantage that negative items have over neutral items, which is shown frequently in literature (Talmi, Luk, et al., 2007; Mather & Nesmith, 2008; Monnier & Syssau, 20008; Brown & Schaefer, 2010; Majerus & D'Argembeau, 2011. This effect is not illustrated in the ERP data however, as there is a consistent main effect of arousal on ERP waveforms and the Dm effect, recorded at encoding. The increased Dm effect observed in the ERP data for higher arousal items does not translate into enhanced recall performance; this is because there are no cognitive mediating factors to assist the emotional items (as explained above), which results in their enhanced memory. It is proposed that this increased and more positive going Dm activity for higher arousing items over low-arousing items observed in the ERP data instead reflects the initial processes of the long-term memory consolidation by modulation. This increased activity reflects the initial increased resources that higher-arousing items automatically capture (Olofsson et al., 2008; Olofsson & Polich, 2007). This increased activity could also reflect the increased activity of the amygdala often recorded at encoding (Hamann et al., 1999; Tabert et al., 2001), which in turn then influences modulation process and long term consolidation of highly arousing items (McGaugh, 2004). The amygdala has reciprocal projections to other brain regions (namely the medial temporal lobe, and associated memory systems), where is it able to modulate the activity crucial to the consolidation of memories over a period of time, to create long-lasting emotional memories (McGaugh, 2004; Phelps, 2004; LaBar & Cabeza, 2006). This theory is supported by the work of Sommer et al., (2008), who found that even in the absence of cognitive mediating factors, there is an arousal-dependant activity in the amygdala at encoding, which predicts subsequent recall.

The ERP data in this study is consistent with the general encoding processes of emotional stimuli, which are outlined in the literature (Watts et al., 2014). The data confirmed robust Dm effects across all three time-widows, for both the high-arousal and low-arousal condition. It is worth noting however; unlike previous studies (see 2.3 and 3.3 Results, Chapters 2 and 3), there were no significant Dm effects reported for the neutral condition, in any of the recorded time windows. The strong Dm effects for high and low-arousal items observed in the early 200-400ms time window, correspond with the early effects often observed in the literature relating the initial capture of attentional and perceptual resources (Duarte et al, 2004; Otten, Sveen & Quayle, 2007). This early capture of resources is consistent with the literature, which proposes affective arousing stimuli are attended to rapidly, due to their intrinsic motivational and evolutionary relevance (Schupp, et al., 2006; Olofsson et al., 2008; Walker et al., 2011). The LPP (late positive potential) is often observed in the middle 400-800ms time window (Codispoti et al., 2012), as demonstrated in our study and is widely reported in the literature across both fronto-central (Friedman & Trott, 2000; Otten et al., 2007) and centro-parietal (Fabiani et al., 1990) sites. The data from this investigation confirms both regions, as the LPP Dm effects for both the high and low-arousal conditions are observed globally across anterior and posterior regions. This LPP is generally sustained over time and is thought to reflect the engagement of post perceptive attentional resources and enhanced elaboration, which are required to successfully encode items in memory (Paller & Wagner, 2002; Codispoti et al., 2007; Olofsson et al., 2008). The LPP tends to be distributed over the whole scalp, with a maxima at posterior sites (Watts et al., 2014) and as our data shows, the LPP is recorded globally for both high and low arousal items, with both the high and low-arousal conditions observing strong Dm effects at all three lateralities across the posterior region. The strong Dm effects observed in the later 800-1500ms time window are consistent with evidence form the literature, which suggests a late LPP or slow-wave. This late LPP is thought to reflect the sustained engagement of attentional resources and the manipulation of information in working memory, which is crucial to the encoding of affective stimuli in memory (Schupp et al., 2006; Olofsson et al., 2008; Leutgeb, et al., 2009; Schienle et al., 2011; Watts et al., 2014). The literature has reported effects at both frontal and posterior sites in a time window ranging from 800-2000ms (Mangels et al., 2001; Otten & Rugg, 2001; Kim et al., 2009; Caplan et al., 2009). These effects are thought to be a reflection of working memory processes modulating the encoding of information in memory. These effects are consistent with the global Dm effects obtained in this study, at both frontal and posterior sites, which show robust Dm effects for high-arousal and low-arousal items. This data provides support for the working memory and cognitive control theory for encoding affective images (see 2.4 Discussion, Chapter 2); arousing images capture initial attentional resources, which are maintained and elaborated before finally being subject to a manipulation using working memory resources, in order to be successfully encoding in memory above neutral images (Watts et al., 2014). Furthermore, this study demonstrates that this process of encoding affective images occurs even when they are presented in a true pure-list paradigm and results in an enhanced encoding for arousing images above that of neutral images.

Looking at the effects observed in the ERP data however shows there are some areas that require further consideration. Looking at Figure 4.4 it appears that the Dm effect for high and low arousal items post ~1000ms is considerably smaller across posterior regions; specifically for low-arousal items. Despite there not being a significant interaction involving the factor of A-P in the 800-1500ms analysis time window, given the important effects obtained at posterior sites in the previous studies (see 2.4 and 3.4 Discussion, Chapters 2 and 3) and the literature outlining LPP and late LPP effects at posterior sites (Ruchkin, Johnson, Mahaffey & Sutton, 1988; Garcia-Larrea & Cezanne-Bert, 1998; Mangels et al., 2001) it was decided to investigate this observation further. Subsidiary analysis on both the high and low-arousal condition in the 800-1500ms time window, revealed significant Dm effects for high-arousal items across all anterior regions (Left, $ps = .038$; Midline, $ps = .014$; Right, $ps = .015$) and all posterior regions (Left, $ps = .015$; Midline, $ps = .004$; Right, $ps = .059$. However, the Dm effect for low-arousal items was only significant across anterior regions (Left, $ps = .052$; Midline, $ps < .003$; Right, $ps = .010$), with no effects across posterior regions reaching significance (all $ps > .16$). These effects reflect the observations noted in figure 4.4 and show the significant effects of memory observed in the 800-1500ms time window for low-arousal items are primarily driven by Dm effects across anterior regions. As mentioned, given the important effects obtained at posterior sites in the previous studies (see 2.4 and 3.4 Discussion, Chapters 2 and 3) and the literature concerning LPP effects at posterior sites (Ruchkin et al., 1988; Garcia-Larrea & Cezanne-Bert, 1998; Mangels et al., 2001), this is a surprising finding. This evidence suggests that it is likely the factor of arousal that is driving the sustained manipulation of stimuli in working memory and producing the strong Dm effects across posterior sites for high-arousal items. Hence, the images in the high-arousal condition are able to recruit the additional resources and sustain their activity in working memory (as reflected by the late LPP effects ; Schupp et al., 2006; Olofsson et al., 2008; Leutgeb, et al., 2009; Schienle et al., 2011; Watts et al., 2014), however the low-arousal items are not arousing enough to do so. Evidence from the literature suggest greater activity in the amygdala occurs for items that are more highly arousing; furthermore, only items of the highest arousal level were able to enhance memory (Canli, Zhoa, Brewer, Gabrieli & Cahill, 2000). Cahill et al., (2000) and Hamann (2001) suggest this could reflect a minimum threshold of arousal needed enhance memory, hence engage the additional working memory resources in the later time window. Future research will be needed to fully examine the possibility that arousal is a key driving force behind the working memory and cognitive control theory, of affective stimuli encoding.

A second surprising finding from the ERP results, is the reduced Dm effect observed in the neutral condition, as there were no significant Dm effects recorded across any of the three time windows for neutral items, despite the relatively high recall rate (mean recall = .329). This is in stark contrast to the previous studies (see 2.3 and 3.3 Results, Chapters 2 and 3), which observed strong Dm effects in the pure-neutral condition ranging from ~250 -1500ms, with similar recall rates reported. One possible explanation could be to do with the semantic relatedness of neutral items compared to negative items. The inherent semantic relatedness of negative items is one of the explanations offered to clarify why negative items are remembered with enhanced recall compared to neutral items (Talmi, Schimmack, et al., 2007; Talmi, Luk et al., 2007; Talmi & McGarry, 2012). The notion stands that negative items have an advantage as they are naturally more related to each other, which aids their organisation and ultimately enhances their encoding in memory, in a way that neutral items cannot utilise. The reduced Dm effects of this study could reflect the possibility that in the absence of other cognitive mediating factors, negative items are able to utilise their relatedness and enhance memory, which is reflected in the strong Dm effect; however, neutral items are unable to exploit the relatedness of the items, hence have a reduced Dm effect. This effect is mirrored in the behavioural results, which show the negatively arousing items have a higher recall rate, as they can utilise the organisation offered by the semantic relatedness of the items to aid encoding, whereas the neutral items cannot use this process. This theory goes someway to explain the effects of this study, but does not explain why there was a robust Dm effect observed in pure-neutral lists from previous studies. It is worth noting that although the Dm effect for neutral items was not significant in this investigation, there was a trend for subsequently remembered items to be more positive going than subsequently forgotten items, through a time window ~300-800ms. This time window corresponds with effects reported in the literature, with neutral items tending to have a later onset for the Dm effect compared to negative items (LaBar & Cabeza, 2006). Similarly this effect would correspond with the effects of the LPP, which reflect an engagement of post perceptive attentional resources (Codispoti et al., 2007; Olofsson et al., 2007). Evidence that these resources were somewhat engaged could explain the associated recall rates for the neutral items. The results of this study also support the findings of the previous investigation (See 3.3 Results, Chapter 3) that found a marked cancellation of the Dm effect post ~1100ms, with this present study also observing that the Dm effect for pure neutral items became reversed ~1100ms. This finding could again reflect how neutral items are unable to make use of the semantic relatedness, which would aid the sustained attentional resources and manipulation in working memory that enhances memory. One important difference to note between the previous work (See Chapters 2 and 3) and the present study is the smaller sample size used in this investigation. This study only used 19 participants, compared to 27 participants and 34 participants, used in the previous studies respectively. The lack of statistical power from using a small sample, could explain why there were no Dm effects observed in the neutral condition in this study. As the results are inconsistent between studies, future research is needed to clarify if the reduced Dm effect for neutral items observed in this study is due to low statistical power or is an effect unique to this true pure-list paradigm, involving semantic relatedness.

This study highlights some important factors that require further consideration. Several studies from the literature have highlighted a sex-difference in the activity of the amygdala recorded at encoding; males tend to show increased activity specifically at right sites, whereas females tend to show increased activity in the left of the amygdala, in response to arousing stimuli (Cahill et al., 2001; Canli, Desmond, Zhao & Gabrieli, 2002; Cahill, Uncapher, Kilpatrick, Alkire & Turner, 2004; LaBar & Cabeza, 2006; Sommer, 2008). The exact mechanisms which underlie such differences are still widely unknown, however this remain a crucial area of future research if studies are to fully establish the exact nature of amygdala activity at encoding (as presented in this study) and the impact sex-differences can have on these effects.

This study aimed to remove potential mediating cognitive factors from EEM, which are known to enhance memory; such as distinctiveness and attention (Talmi, Schimmack et al., 2012; Talmi, Luk, et al., 2007; Talmi & McGarry 2012; Talmi, 2013). Although we can be confident that the true pure-list design of this study removed the relative distinctiveness that is able to enhance memory, no exact measures were used to manipulate attention. The response on the SAM to all three conditions showed no significant differences, so we can be reasonably confident that there was no selective attention advantage for any condition. However, attention has been shown to be a powerful mediator of emotion and memory interactions (Talmi, Schimmack et al., 2007; Talmi, Anderson, Riggs, Caplan & Moscovitch, 2008; Talmi & McGarry, 2012; Pottage & Schaefer, 2012). The extent to which attention interacts with emotional memory formations is a matter of debate; some evidence suggests attention only mediates memory for positive valenced stimuli but not for the subsequent memory of negative items (Talmi, Schimmack et al., 2007), whereas other studies suggests attention can be shown to mediate negatively valenced stimuli (Pottage & Schaefer, 2012; Talmi & McGarry, 2012). Future studies are needed to fully establish the effects of attention of the immediate EEM.

This study should also be repeated with an implement divided attention task, to truly eliminate attention as a potential cognitive mediator and fully establish the effects of arousal at encoding in the absence of enhancing cognitive factors.

One cofounding factor that has not been investigated by this study is the concept of relatedness as a mediating cognitive factor. It is suggested that emotional items have an inherent advantage at being more organised and related than neutral items, which contributes towards the enhanced encoding of emotional items over neutral items (Talmi & McGarry, 2012). Talmi and colleagues have recently shown that when neutral items are controlled for semantic relatedness, to the same level as negative items, the mnemonic memory advantage for negative items disappears and recall for negative and neutral items is equal (Talmi, Schimmack et al., 2007; Talmi, Luk et al., 2007; Talmi & McGarry, 2012). The semantic relatedness of items was not controlled in this present study; hence there was a higher recall rate for negative and arousing items compared to neutral items. Given the work by Talmi et al., (2007; 2012), it would be expected, if this study was repeated using neutral items controlled for semantic relatedness, that recall rates would be comparable across all three conditions. In order to completely address the impact that arousal has at encoding in the absence of cognitive mediating factors, further research could implement this true pure-list experimental paradigm using neutral items controlled for semantic relatedness. This would allow a more accurate comparison between the levels of arousal, and bring all conditions up to a comparable level, regarding the absence of presence of potential memory enhancing cognitive factors. In addition, this paradigm would also address if the lack of Dm effect in this study was because neutral items were unable to draw upon the same levels of organisation and relatedness, which enhances the links in memory in a process negative items are able to utilise.

This study focused primarily on the effects of arousal as this is the dimension usually implicated as the most important driving force behind EEM (Talmi, Schimmack et al., 2007; Kensinger & Corkin, 2004; McGaugh, 2004). It is important to note that although the images in this study varied on arousal levels, hence isolating the factor of arousal, they also differed on measures of valence. Although both sets negative images were rated on the unpleasant side of the valence scale, the degree to which they were deemed unpleasant significantly differed; with high-arousal images being more unpleasant than low-arousal images. Experiments isolating the effects of valence typically compare items that are unpleasant with items that are rated pleasant (Schupp, et al. 2000; Schupp, et al. 2007) and often report that unpleasant stimuli elicit stronger effects of emotion than pleasant stimuli (Ochsner, 2000; Crawford & Cacioppo, 2002). The extent to which valence influences the EEM is a topic of much debate (Kensinger & Corkin, 2004; Kensinger & Schacter, 2008; Kensinger, 2009), with distinct neural networks implicated for the effects of valence over arousal. The effects of valence are thought to be driven by a prefrontal cortex –hippocampal network that controls encoding processes (Kensinger & Corkin, 2004), whereas arousal effects are thought to depend primarily on the amygdala-hippocampal networks (McGaugh, 2004; McGaugh, 2000; Cahill & McGaugh, 1998). As the valence ratings of the images used in this study were both on the same unpleasant dimension, we are confident that the effects observed were driven primarily by changes in arousal level. An area of interesting future research however, would be to examine if the effects of high and low-arousal differ under the pleasant valence dimension in the same way as the unpleasant dimension, as shown in this present study.

The second aim of this study to address the possibility that pure-negative lists used in previous studies (Watts et al., 2014 and Chapter 3) were acting as a pseudo-mixed list. The recall results from previous work that used negative pure-list conditions with intermixed arousal levels (see Results 2.3 and 3.3, Chapters 2 and 3) demonstrated that there was no significant difference between the recall rates of the low-arousal items and neutral items. This was a surprising finding, given the importance that arousal plays on encoding (McGaugh, 2004) and the mnemonic advantage negative items usually have over neutral items (Talmi, Luk et al., 2007). Furthermore, the previous studies (see Results 2.3 and 3.3, Chapters 2 and 3) also demonstrated a significant difference between the recall rates if the high-arousal and low-arousal items. Although this is not a surprising finding in itself, taking the above two results together formed a conclusion, which stated pure-list studies that use intermixed levels of arousal may act as a 'pseudo-mixed' list. Whereby, the high-arousal items may have preferentially captured the processing resources at the expense of encoding low-arousal items; much in the same way that neutral items face a disadvantageous balance of attentional processing resources, with the majority of working memory resources required to aid encoding applied to negative items, in a classic mixed-list condition. Hence the pure- lists condition of previous results with intermixed levels of arousal, may have been acting as a 'pseudo-mixed' list.

The results of the present study confirm this suspicion and suggest that the pure-negative lists with an intermixed levels of arousal, were indeed acting as a pseudo-mixed list. This study observed a significant difference (1 tailed $p = .049$) between the recall rates of the low-arousal condition (mean recall rate = .353) and the neutral condition (mean recall rates =.329). This is in contrast to the previous study, which observed comparable levels of recall between low-arousal (mean recall rate =.31 and neutral (mean recall rate = .30) items (see Results 3.3, Chapter 3). Although the effect observed in this present study is a marginal effect, the large effect size (.38) shows it to be a strong finding. This shows that when images are presented in a true pure-list (with no intermixed arousal levels), the recall rate for low-arousal items are significantly higher than neutral items. Furthermore, the comparable recall rates between the high-arousal (mean recall rate = .358) and low-arousal items (mean recall rate = .353) suggest that when the negative items are presented in lists with homogenous arousal levels, there is no longer a competition for resources and both the high and low-arousal conditions have access to all encoding resources available; hence, equal recall rates. This interpretation is consistent with the arousal-biased competition (ABC) model devised by Mather and Sutherland (2011). They propose that when items of intermixed arousal levels are presented together, it creates an ABC; whereby, when a highly arousing items is presented it creates a competition bias to prioritise any further highly arousing items, as they have more adaptive significance. As such, this would mean when high and low arousal items are intermixed, the high-arousal items would be prioritised and encoded more efficiently as they have a greater adaptive significance. However, when items are presented with homogenous arousal levels, as in this present study, there can be no ABC.

Overall, this evidence therefore suggests that when negative items are presented in a condition with intermixed arousal levels, the high-arousal items preferentially capture the processing resources, at the expense of low-arousal items in the pure-list. However, when items are presented in true pure-list conditions (with no intermixed arousal levels) as in the present study, the recall rates between high and low-arousal items are comparable, as the low-arousal items have full access to all the processing resources which aid encoding; making the recall rates for low-arousal items comparable to those of high-arousal items. For completeness, to ensure the paradigm used in this study did not create an overall higher recall rate, the mean recall rate of negative items in this study was computed by combining the recall rates from high and low-arousal items to compare to the negative recall rates of previous studies. The overall result for negative recall in this present study (mean negative recall rate = .35) is comparable to the negative recall rates obtained in the pure-lists from previous studies (mean negative pure-lists recall rate = .34: see 3.3 Results, Chapter 3), showing the recall rates are comparable across paradigms and studies. Taken together these findings suggest intermixed levels of arousal presented in previous pure-list conditions, were acting as a pseudo-mixed list by taking advantage of the relative distinctiveness of the high-arousal items, at the expense of encoding low-arousal items. Furthermore, the results also suggest that using the intermixed levels of arousal for negative items within a mixed-list condition also fall to the same fate; the recall rates of low-arousal items from a mixed-list condition, also appear reduced compared to the recall rates of low-arousal items obtained in this present study. These findings have important implications for future studies investigating EEM, using paradigms that involve intermixed levels of arousal, not only in a pure-list paradigm but also a mixed-list condition. Future studies must be cautious about the conclusions they draw regarding recall rates of items of different arousal, when they have been presented in an intermixed list; as this study demonstrates, items of higher arousal can preferentially capture more processing resources at the expense of successfully encoding lower arousal items.

These findings are also supported by the event-related potential results. Watts et al. (2014) did not find a robust Dm effect across the low-arousal items when they were presented with intermixed arousal levels, in a pure-list condition. This would be consistent with the notion that when the negative items are presented with intermixed arousal levels, the high-arousal items are preferentially capturing the majority of the processing resources at the expense of successfully encoding low-arousal items; hence why the low-arousal items had a reduced Dm effect. However, in this present study, there was a robust Dm effect across all time windows (primarily across Midline and Right electrode sites); suggesting when items are presented in a true pure-list condition (with no intermixed arousal levels), the low-arousal items are able to capture all the necessary processing resources for successful encoding, which is reflected in the strong Dm effect.

It is worth noting however, that these results are in contrast to those obtained in Chapter 3 (see 3.3 Results, Chapter 3); where there was a robust Dm effect for low-arousal items across all time windows, despite the items being presented with intermixed arousal levels, in a pure-list condition. The strong Dm effect of those low-arousal items could reflect the increased processing resources required to successfully encode the low-arousal items, when they are competing against the initial capture of resources from the high-arousal items. A higher level of cognitive effort and elaborative processing is known to increase overall brain activity and specifically the Dm effect (Gray et al., 2005; Paller & Wagner, 2002; Caplan et al., 2009; Otten et al., 2007), hence the strong Dm effect recorded for low-arousal items under those conditions. This work takes an initial step to uncover the ERP activity surrounding the successful encoding of items of different arousal levels and how this differs depending on what paradigm is used; however further research is needed to fully establish the exact nature of neural processes which underlie the successful encoding of low-arousal items, when they are presented in both intermixed arousal levels and true pure-list paradigms.

4.4.1 Conclusions

Overall this investigation has yielded some interesting results. Firstly, the findings of this study offer support to both the cognitive account of immediate EEM and the modulation hypothesis for long-term emotional memories. The results suggest that when cognitive mediating factors are removed, there is no advantage for higher arousing items over lower arousing items in the immediate EEM. That is to say, arousal alone is not enough to drive the immediate effects of EEM. When cognitive factors are removed, only the mnemonic advantage that emotional items have over neutral items remains; as previously demonstrated in pure-list studies (Watts et al., 2014; Talmi, Luk et al 2007). In addition, the ERP results of this study suggest a significant effect of arousal upon the Dm effects at encoding. This provides evidence to support the modulation hypothesis and the long-term consolidation of emotional memories. The linear effect that arousal has upon the ERP data in this study corresponds closely with the effects reported in the literature of the amygdala and its projections to modulation other key memory consolidation regions. The Dm activity surrounding arousal was itself not enough to predict immediate memory enhancement (as has been shown in the literature: Hamann et al., 1999; Talbert et al., 2001). It does however correspond with activity often reported at encoding, which predicts subsequent memory performance after a delay; once the modulation and consolidation processes of emotional memories have been allowed to take place. To truly verify this theory further research needs to be conducted, testing subsequent memory both immediately after encoding and after a delay. Secondly, this study has demonstrated that when using a pure-list design, if intermixed arousal levels are included in a pure-list paradigm, they can in fact act as a ‘pseudo-mixed’ list. That is to say, the items that are deemed more arousing preferentially capture the majority of the processing resources at the expense of successfully encoding lower arousal items. This works in much the same way that Watts et al. (2014) demonstrated, whereby neutral items presented in a mixed list with negative items have a reduced recall rate and Dm effect, as the processing resources are preferentially allocated to negative items at the expense of encoding neutral items. This finding has implications for the use of future mixed and pure-list paradigms, which investigate the effects of emotion and memory and suggests that arousal is an important factor to take into consideration when designing studies

Chapter 5: Using an ERP study to investigate the role that distinctiveness, semantic relatedness and attention play in the immediate EEM

5.1 Chapter Overview

This work aims to further the research into the immediate EEM by addressing some of the outstanding questions presented by the previous work. Chapters 2 and 3 examined the role that distinctiveness played in the immediate EEM; however the behavioural literature outlines several other potential cognitive mediating factors. This present study therefore aimed to investigate the role of semantic relatedness and attention, in the immediate EEM. Together with the factor of distinctiveness, this study examined the potential interaction of these cognitive mediating factors and how they contributed both individually and collectively to the immediate EEM. In addition, this study also utilised ERP methods, to further the research into EEM and uncover the neural correlates of these cognitive mediating factors. Firstly, the results found partial support for the two-step model of distinctiveness outlined in previous studies (see Chapters 2 and 3); however, it is likely that part of the two-step model is determine by differences in inter-item relatedness. Secondly, contrary to the findings of Talmi & McGarry (2012) pure-negative stimuli still had mnemonic memory advantage over pure-neutral items; therefore distinctiveness and relatedness alone are not sufficient to account for the immediate EEM. Furthermore, the results revealed that overt attention only appeared to have a significant effect in the mixed-list condition. This suggests that the EEM present for related items in the pure-list condition, occurs beyond the effects of overt attention and may rely on pre-attentive processing resources and other unique processing routes.

5.1.1 Introduction

Emotion is known to convey an enhancing benefit for memory, with emotional events often gaining a privileged status in memory (LaBar & Cabeza, 2006). Emotional memories are often remembered better and have an increased sensorial detail, confidence and accuracy compared to non-emotional or neutral stimuli (Schaefer & Philipot, 2005; LaBar & Cabeza, 2006). These markedly different characteristics attributed to emotional memory and the phenomenon surrounding a memory advantage for emotional items has recently been coined the emotional enhancement of memory (EEM).

Despite the long history of research into EEM, relatively little is known about the exact cognitive mechanisms and underlying neural correlates of emotion and its effects on memory (Schaefer, Pottage & Rickart, 2010). Recently the field of cognitive neuroscience has begun to uncover the neural mechanisms responsible for enhancing the memories of emotional events and the long term effects of EEM (LaBar & Cabeza, 2006). The predominant explanation of EEM is the modulation theory or hypothesis (Cahill & McGaugh, 1998; McGaugh, 2000; McGaugh & Roozendaal, 2002; McGaugh, 2004). The modulation or consolidation hypothesis has extensive support from the literature and primarily implicates the amygdala as a key structure in the role of consolidating arousing memories (McGaugh, 2004; Phelps & LeDoux, 2005; Kensinger & Schacter, 2008). The modulation hypothesis specifically postulates the basolateral complex of the amygdala (BLA) selectively mediates the memory-modulating effects of adrenal stress hormones and other neurotransmitters; the BLA then in turn projects to further brain regions such as the hippocampus, which consolidates the information leading to emotional experiences being well remembered (McGaugh, 2004). The modulation hypothesis has extensive evidence from both animal and human studies to support the notion that the post-encoding process of consolidation is a crucial step in the memory formation process and causes emotionally arousing events to form long lasting and durable memories, that are resistant to loss (McGaugh, 2000; McGaugh, 2004). The process of consolidating emotionally arousing events is widely thought to a take a period of time; suggesting the longer the period of time the consolidation process has to take place, the stronger the observed effects of emotion on memory would be (Hamann, 2001). The modulation hypothesis is supported from an evolutionary theory perspective, which suggests that remembering arousing events (negative or positive) is an adaptive function; the enhanced memory for arousing stimuli ensures the information will be readily accessible to aid with future situations of survival or reproductive success (Hamann, 2001). Hence, the modulation hypothesis offers a concrete explanation for the prolonged effects that emotion has upon memory; however as Talmi notes, the modulation hypothesis does not account for the mnemonic effects that emotion has upon immediate memory tests (Talmi, Luk, McGarry & Moscovitch, 2007).

Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack, Paterson & Moscovitch, 2007;Talmi & McGarry, 2012; Talmi, 2013) provide evidence to show emotion can enhance even immediate memory, an effect which is beyond the account of the modulation hypothesis. Talmi, Luk et al., (2007) suggest the immediate effects of EEM are instead due to cognitive mediating factors (see 1.7 Immediate EEM, Chapter 1); whereby, changes in the cognitive attributes of emotional stimuli, results in an mnemonic advantage for emotional items over neutral items.

There is a wide range of behavioural evidence to support the cognitive mediation account of EEM and the literature outlines several cognitive factors, which play a key role in EEM. The cognitive factor of attention has been implicated in a range of studies (Pottage & Schaefer, 2012; Talmi, Schimmack et al., 2007; Schmidt & Saari, 2007) as being an important part of immediate EEM; it is suggested emotional items preferentially capture visual attention and are processed and encoding quickly, in a high-priority mode (Pottage & Schaefer, 2012; Mermillod, Droit-Volet, Devaux, Schaefer & Vermeulen, 2010). The distinctiveness of emotional items is another well investigated cognitive factor, implicated in the immediate EEM (Watts, Buratto, Brotherhood, Barnacle & Schaefer, 2014; Talmi, Luk et al., 2007; Schmidt, 2002; Hunt & McDaniel, 1993). It is posited that when emotional and neutral items are intermixed, the emotional items become relatively distinct compared to the background of neutral items; hence the emotional items preferentially capture more attention at the expense of neutral items, which aids the encoding of emotional stimuli (Watts et al., 2014). A third factor which has only recently attracted research from the literature is semantic relatedness. It is suggested that the inherent relatedness of negative items, contributes to a more organised structure of encoding and results in a memory advantage (Talmi, Luk et al., 2007; Talmi, Schimmack, et al., 2007; Talmi, 2012). Another factor that has been considered as playing a role in the immediate EEM is the self-referential processing related to emotional stimuli; emotional items tend to processed relating to oneself, which can lead to them being processed more efficiently and enhance subsequent memory (Conway & Dewhurst, 1995; Conway & Pleydell-Pearce, 2000; Schaefer & Philippot, 2005). Likewise, the strategic processing of emotional information through regulation is also known to have a strong impact upon emotion and memory interactions (Richards & Gross, 2000; Ochsner & Gross, 2005). All of these factors are known to have important consequences to the interaction and effects emotion has upon memory. Hence, the current account of EEM posits that the mediation theory offers an explanation for the immediate effects of EEM and the modulation hypothesis can account for the long-term effects of EEM (Talmi, 2013).

The prolonged effects of EEM have been long been noted in a wealth of behavioural studies (see McGaugh 2004 for review). Furthermore, the field of cognitive neuroscience has developed the modulation hypothesis (McGaugh, 2004), which offers a neurobiological basis to support these behavioural findings and provide an encompassing explanation of the long-term memory enhancement for emotionally arousing stimuli. Likewise, the cognitive mediating theory has a wealth of behavioural evidence to support the cognitive factors which can play a key role in the immediate effects of EEM (Talmi & McGarry, 2013; Talmi, 2012). However, it is only recently that the scientific community has turned its attention to try to uncover the underlying neural mechanisms that facilitate these cognitive mediating factors and how they exactly influence the immediate effects of emotion upon memory.

A recent study by Watts et al., (2014) has attempted to shed some light on the neural correlates of the immediate EEM and completed an event-related potential (ERP) study to investigate the cognitive factor of distinctiveness in EEM. The study followed up on the behavioural work of Hunt et al., (1993) and Schmidt (2002), which isolated the factor of relative distinctiveness as having a strong impact upon emotion and memory. Watts et al., (2014) and the study presented in Chapter 3, found that the relative distinctiveness of emotional items in a mixed-list condition does lead to an enhanced subsequent memory; in addition, there is also a significant reduction in the amount of neutral items recalled in a mixed-list condition. This finding was supported by the ERP findings which showed a robust subsequent memory effect for negative items, however the subsequent memory effect for neutral items in the mixed-list condition, were significantly reduced across posterior sites. These results were interpreted in accordance with a two-step model of processing, which proposed that there is an initial relevance detection mechanism that occurs using attentional resources, to establish which stimuli require additional processing resources. As a consequence of this first step, the second step of the model is engaged and involves maintaining and manipulating these specific stimuli in working memory; a process thought to enhance the likelihood of successful encoding. As a result of this two-step model, in a mixed list condition, negative items preferentially capture the initial attentional resources as outlined in the first step of the model. This then engages the second step for negative items and results in a higher level of successfully encoded items. Neutral items in the mixed-list condition however, are outcompeted in the first step of the model; as consequence they do not engage the second step and the encoding potential is ultimately reduced. This model provides strong support for a significant role of distinctiveness in immediate EEM.

As mentioned however, there are several potential cognitive mediating factors outlined in the behavioural literature that play a role in the immediate EEM. Therefore this present work aims to address some of the outstanding questions that remain unanswered from previous studies and explore the potential interaction of other cognitive mediating factors; specifically the role that semantic relatedness and attention can play in the immediate EEM.

Addressing the role of semantic relatedness, although not as well researched in the literature as other cognitive mediating factors, as mentioned above relatedness has been implicated in several behavioural studies as playing a role in the formation of emotional memories and has been shown to be a very important factor to consider in the design of experiments investigating EEM (Talmi & McGarry, 2012; see 1.7.2 Relatedness, Chapter 1 for more details). The idea of using the sematic relatedness of stimuli as a processing tool to facilitate memory is not new; the levels of processing theory proposed by Craik and Lockhart (1972), demonstrated that a deeper semantic level of encoding will lead to a stronger memory. Hunt et al., (1993) have also shown how organisation can benefit memory, as it facilitates the creation of forming links between items at encoding, which aids memory. It is suggested that relatedness can play a role in EEM, as emotional items have a higher inherent level of semantic relatedness and organisation; therefore it is easier to create thematic links at encoding, which could facilitate memory and contribute to EEM (Talmi, Luk et al., 2007). Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) have devised a set of negative and neutral stimuli in which they have controlled for semantic relatedness. To create these stimuli sets, images were assessed for inter-item relatedness using a 7-point Likert scale and based on the picture content; this process gave every image a relatedness score. Using these ratings the stimuli were chosen so that both the negative and neutral image sets were matched in their relatedness scores. Using this image set, studies have shown that the mnemonic advantage for emotionally negative items over neutral items is abolished; as the subsequent recall performance observed for negative and related neutral items, is reported as being equal (Talmi, Luk et al., 2007; Talmi, Schimmack et al. 2007; Talmi & McGarry, 2012). These surprising findings highlight the impact relatedness can have upon EEM. To see if we can replicate these behavioural results and remove the EEM advantage for negative items, when all the items are controlled for inter-item semantic relatedness, this present study used the same stimuli set (as described above). Furthermore, this study aims to advance these behavioural findings and use ERP recordings to uncover the neurological correlates of relatedness to explain how relatedness influences the immediate EEM.

The behavioural literature (as mentioned above) also outlines the role of attention as a crucial part of the immediate EEM (Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012; Pottage & Schaefer, 2012; Talmi, 2013; see 1.7.3 Attention, Chapter 1 for more details) and it has been shown to be an integral part to the way distinctiveness exerts its influence as a cognitive mediating factor in EEM (Watts et al., 2014). Classically attention and EEM has been investigated by using a divided versus full attention paradigm; whereby participants are required to allocate their attention to a primary task (e.g. encoding image), whilst completing a secondary task (e.g. discriminate an auditory tone). It is thought that completing the secondary task depletes the attentional resources available, whilst leaving pre-attentive attentional resources unaffected (Kensinger & Corkin, 2004; Pottage & Schaefer, 2012). Talmi, Schimmack et al., (2007) implemented a full versus divided attention paradigm and found attention did significantly mediate EEM; however it differed according to valence. Their study found attention for emotionally positive stimuli completely accounted for EEM, whereas attention did not significantly mediate the relationship with EEM when the stimuli were emotionally negative. These findings are in contrast to Pottage & Schaefer (2012), who found that visual attention did significantly mediate the relationship with EEM for emotionally negative images, which suggests emotionally negative items have privileged access to attentional resources and visual attention plays an important role in the formation of emotional memories (Pottage & Schaefer, 2012). The behavioural evidence presented on attention and EEM is conflicting, as Talmi, Schimmack et al (2007) suggest attention does not mediate EEM for negative items, whereas Pottage and Schaefer (2012) found evidence to suggest that visual attention does significantly mediate the EEM for negative stimuli. It has been suggested that these contrasting findings are due to the different secondary (or concurrent) task used by the two studies (Pottage & Schaefer, 2012). Talmi, Schimmack et al., (2007) used an auditory discrimination task, which was therefore tapping into a different sensory modality to the primary task of picture encoding, whereas Pottage and Schaefer (2012) used a visual number discrimination task, which does rely on the same visual sensory modality as encoding a picture. Evidence from the literature has suggested that the processing of emotional stimuli may not be affected by a secondary (or concurrent) task, which does not use the same sensory modality as the primary task (Schupp et al., 2008; Schupp et al., 2007; Schupp et al., 2006); hence Pottage and Schaefer (2012) argue, to ensure the strongest test of pre-attentive resources and processing in EEM, the primary and secondary tasks should both rely on the same type of sensory modality, which in their case was visual. Although conflicting, the behavioural evidence does suggest that attention plays a significant role in the immediate EEM.

The behavioural literature on attention and emotion has paved the way for cognitive neuroscience to implement more precise examinations into the neurological correlates of the role of attention upon emotion (Keil et al., 2001; Schupp, Flaisch, Stockburger, Junhofer, 2006; Schupp et al., 2007; Schupp et al., 2008), however no ERP study to our knowledge has examined the interactions of emotion and attention upon subsequent memory. Talmi, Anderson, Riggs, Caplan and Moscovitch (2008) however, investigated the role of attention on immediate EEM, in an fMRI investigation. The study found, activation in the fusiform gyrus was associated with enhanced picture processing and attention, but only when the picture was emotional; furthermore, the activation in the fusiform gyrus also correlated with subsequent memory for emotional items (EEM). This study supports the behavioural literature and provides evidence to suggest attention plays a key role in EEM; whereby emotional items involuntarily recruit privileged attentional resources during encoding, which leads to a memory advantage for emotional items and an immediate EEM (Talmi et al., 2008; Pottage & Schaefer, 2012). Therefore this present study aims to investigate the factor of attention and resolve the conflicting behavioural data surrounding the role attention plays on negative items in the immediate EEM.

Based on the evidence outlined above, the aim of this present study is to address some of the outstanding questions regarding the immediate EEM and examine three of the key mediating cognitive factors; distinctiveness, semantic relatedness and attention. This study will use ERP measures to further the research into the neural basis of the cognitive account of EEM and investigate how these factors both contribute individually to the immediate EEM and how they interact to contribute to the immediate EEM.

This present study implemented a mixed versus pure-list design (see Chapter 2 and 3), to manipulate the cognitive factor of relative distinctiveness and investigate how this factor interacts with semantic relatedness and attention. We hypothesise that both the behavioural and ERP results, in line with previous studies, will show that distinctiveness plays a significant role in the EEM, but for mixed lists only (Watts et al., 2014; Talmi, Luk et al., 2007). We expect to find a significant difference between the amount of negative and neutral items recalled in the mixed-list condition, coupled with a significant reduction in the amount of neutral items recalled in the mixed-list compared to the pure-list condition (Watts et al., 2014). We expect the behavioural data to be reflected in the ERP results, with a strong Dm effects for negative items in the mixed-list condition and a reduction or cancellation for the Dm effect for neutral items in the mixed-list condition; specifically across posterior sites (Watts et al., 2014).

This study will use the same image stimulus sets devised by Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) that were controlled for relatedness, to see if we could replicate the behavioural results and remove the EEM advantage for negative items. The study will use a between subjects design, with half the participants seeing the images in a mixed-list condition and the other half viewing them in a pure-list condition (implementing the mixed versus pure list design, outlined above). We hypothesise that the memory mnemonic memory advantage for negative items over neutral items in the pure-list condition will be removed, in accordance with the findings of Talmi Luk et al. (2007); with the recall rates between the pure-negative and pure-neutral condition being comparable. In addition, ERP data was recorded, which is a unique addition to the study, that Talmi and colleagues are yet to investigate. This will allow us to examine the neural correlates and investigate the processing mechanisms responsible for the factor of relatedness. We expect our ERP results to reflect the behavioural findings of Talmi, Luk, et al., (2007), with a strong and comparable Dm effect for the pure-negative and pure-neutral condition.

Due to the constraints of finding a suitable paradigm to measure attention that was compatible with EEG recording, we devised a new and unique paradigm, which provided an indirect measure of attention. Rather than a classic full versus divided attention paradigm, this paradigm did not use a concurrent task but a secondary number task that was presented after the image, rather than at the same time (see 5.2 Methods). The task will involve completing a simple number task after the presentation of every image. Based on previous research (Pottage et al., 2012), we expect that emotionally negative images will capture the most attention and deplete the processing resources available to complete the following number task. Recording the reaction times and accuracy to the number task presented after the image, will provide a measure of performance on the number task and as such, provide an indirect measure of attention and an index of how attention grabbing the previous image was. Crucially, the number task is visual and in the same sensory modality as encoding an image. We expect the reaction times (RT) and accuracy to the number task to be slower and less accurate following a negative image compared to a neutral image, which is in accordance with previous attention studies (Talmi & McGarry, 2012; Pottage & Schaefer, 2012) and reflects the attentional resources negative stimuli capture, leaving fewer resources available to focus on a secondary task. In addition, in line with the findings of Talmi and McGarry (2012) we do not expect to find a difference between the RTs for mixed or pure-list conditions, as both list conditions are completed under full attention the same levels of attention will be available to both mixed and pure-lists. We expect accuracy for the number task across all conditions to be high; this reflects that participants are fully engaged with the task and shows there is no reduction in accuracy accounting for faster reaction times, in an accuracy versus RT trade-off.

In order to precisely examine these three factors and the underlying neural mechanisms through which they exert their influence in EEM, we used EEG recordings and event-related potential (ERP) methods to obtain a measure of subsequent memory (Dm effect). The encoding related activity for items which were successfully encoded is separated from the items which were subsequently forgotten; this differential activity and contrast is known as the Dm effect (Paller & Wagner, 2002). This is a well-known neural index, which reflects the successful encoding items in memory and has been implemented across a wide range of studies (Watts et al., 2014; Bridger & Wilding, 2010; Voss & Paller, 2009; Otten, Quayle, Akram, Ditewig & Rugg, 2006; Reynolds, Donaldson, Wagner & Braver, 2004; Duarte, Ranganath, Winward, Hayward & Knight, 2004; Rugg, Otten & Henson, 2002; Mangels, Picton & Craik, 2001; Paller, Kutas & Mayes, 1987). Studies have found that the Dm effect can move both spatially and temporally, which suggests the Dm effect reflects the existence of many different levels of encoding processes relating to the formation of memories (Otten, Sveen & Quayle, 2007; Friedman & Johnson, 2000; Paller & Wagner, 2002). However, many studies have consistently report finding a larger positivity for negative items compared to neutral items and more positive going waveforms for subsequently remembered items, compared to forgotten items (Paller & Wagner, 2002; Dolcos & Cabeza, 2002; Schupp et al., 2006; Watts et al., 2014). Effects frequently reported in the literature surrounding the Dm effects for emotional stimuli have observed early Dm effects (~ pre 400ms), which are thought to reflect the initial stimulus driving properties of emotional stimuli attributed to the motivational and evolutionary significance of emotional items (Walker, O'Connor & Schaefer, 2011; Olofsson, Nordin, Sequeira, Polich, 2008; Schupp et al., 2006). This early Dm effect coincides with effects often observed ~400ms, which have been interpreted as reflecting the attentional engagement of stimuli that can lead to enhanced elaboration (Paller & Wagner, 2002); these effects have been reported at both fronto-central (Friedman & Trott, 2000; Otten et al., 2007) and centro-parietal (Fabiani, Karis & Donchin, 1990) scalp sites. These early ~400ms effects are also known to be sensitive to divided attention tasks (Mangels et al., 2001) and the effects are enhanced when participants are required to process the stimuli with a deeper semantic level of encoding (Otten et al., 2007; Otten & Rugg, 2001; Friedman, Ritter & Snodgrass, 1996). This evidence is consistent with the interpretation that these early effects reflect a perceptual and attentional process, which can aid encoding.

The second component often associated with emotional stimuli is the late positive potential (LPP), which is usually characterised by larger positivity for negative items compared to neutral items. The LPP is observed globally across the scalp with the maxima at posterior sites and is predominantly found in a time range spanning ~400ms-800ms (Codispoti, De Cesarei & Ferrari, 2012). The LPP is widely thought to reflect post-perceptual resources needed to process emotional stimuli, which are sustained in time spanning a ~400ms-800ms time window (Codispoti, Ferrari & Bradley, 2007; Olofsson et al., 2008). Emotional stimuli are also associated with sustained slow waves; this final effect is often called the late LPP and has been observed at later latencies from ~800-1500ms (Leutgeb, Schafer & Schienle, 2009; Schienle, Kochel & Leutgeb, 2011), and in some cases up too 2000ms (Diedrich, Naumann, Maier & Becker, 1997). The effects of both the LPP and the late LPP that are sensitive to affective stimuli correspond to effects reported in the literature, which reflect encoding conditions involving working memory resources (Mangels et al., 2001; Caplan, Glaholt & McIntosh, 2009) and the manipulation and maintenance of information in working memory (Revonsuo & Laine, 1996; Garcia-Larrea & Cezanne-Bert, 1998).

All these studies together provide very useful insights as to the underlying neural correlates of emotion and memory. These findings are a useful starting point upon which to build this study and incorporate how cognitive mediating factors can influence these known neural mechanisms. Using the unique number paradigm (see 5.2 Methods), we expect to find that distinctiveness will play a significant role in EEM, but only in the mixed list condition; this will be reflected with a strong Dm effect for negative items but a reduced Dm effect for mixed-neutral items. Using stimuli controlled for semantic relatedness, we expect will lead to an equal level of recall between the pure-negative and the pure-neutral conditions; this will be reflected with a strong Dm effect for both conditions. Lastly, we expect the behavioural data in response to the number task to be slower, reflecting the increased attentional resources negative items capture and confirming the key role attention plays as a cognitive mediating factor in EEM (Pottage & Schaefer, 2012; Talmi & McGarry, 2012; Talmi et al., 2008; Talmi, Schimmack et al., 2007).

5.1.2 Aims

- To replicate the previous findings on distinctiveness and establish the role it plays when items are controlled for semantic relatedness.
- To establish the role semantic relatedness plays in EEM and see if we can replicate the cancellation of a memory advantage in a pure-list condition, when the stimuli are controlled for relatedness.
- To use a new and unique number paradigm to indirectly measure attention, establish the role attention plays in EEM and how it interacts with distinctiveness and relatedness.
- To further the research into the underlying neural correlates of EEM and uncover how each of these three factors (distinctiveness, relatedness and attention) contribute individually and collectively to the cognitive mechanisms responsible for the immediate EEM.

5.2 Methods

5.2.1 Participants

Forty right-handed adults (13 Males) with a mean age of 24 years (SD = 4.0 years) from Durham University and the surrounding area, with no history of psychiatric or neurological conditions, took part in this study in exchange for £20 cash or course credit. As the experiment contained negative images, all participants completed two screening questionnaires prior to taking part. Any participant who scored above 21 on the Beck's Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) or those who scored above 50 on State Trait Anxiety Inventory (Speilberger, Gorsuch & Lushene, 1970) were excluded from taking part in the study. All participants gave informed consent and the study was approved by the local ethics committee. From the forty participants who took part, twenty were assigned to the mixed-list condition and twenty to the pure-list condition.

5.2.2 Stimuli and Design

This study used realistic colour images, showing both emotionally negative scenes and neutral scenes. The images were obtained from a database that Talmi and colleagues created (see Talmi, Emotion and Cognition Laboratory, The University of Manchester for further details; see Talmi, Luk et al., 2007 and Talmi & McGarry, 2012 for studies using these images); all neutral images were from Google Image™ and the negative image set was created using images from the International Affective Picture System (IAPS: Bradley & Lang, 1994; Lang, Bradley & Cuthbert, 2005) and from Google Image™ (see appendix H). In total there were 192 images used in this study; 96 semantically related neutral images and 96 semantically related negative images. The negative images were semantically related around the constructs of similar valence and arousal, whereas the neutral images were semantically related around the construct of domestic household scenes. All images were resized 400 x 300 pixel format and displayed centrally at 1024 x 768 pixels, on a 40cm x 30cm Samsung SyncMaster computer screen (TCO'03 Displays, MagicBright).

The negative and neutral image sets were previously rated by Talmi and colleagues, separately for semantic relatedness. Participants were required to rate how related each individual image was compared to a set of 9 representative images; ratings were done on a 4 – point scale, whereby 1 = very similar and 4 = very dissimilar. This process was completed separately or the negative and neutral image sets. Statistical analysis using Cronbach's alpha showed reliability between the raters was high (α = .902). Furthermore, t-tests showed no significant difference between the ratings of relatedness between the negative image set and neutral image set [t (95) = .210, p > .05]. Talmi and colleagues also rated the image for valence and arousal using the SAM (See 3.2 and 4.2 Methods, Chapters 3 and 4), which confirmed the image sets were significantly different on both valence [t (95) = .048, $p < .05$] and arousal [t (95) = .004, $p > .05$] measures.

In addition to the 192 test images, there were also 64 buffer images (32 negative and 32 neutral buffer images) included in the experiment. The buffer images were inserted as the first and last image in each block, to reduce primacy and recency effects (Talmi, Luk et al., 2007; Talmi & McGarry, 2012). The buffer images were randomly allocated, however the buffer images used in the pure-list condition always corresponded with the valence of the image block (i.e. neutral pure-list had only neutral buffers, negative pure-lists only had negative buffer images). These buffer images were excluded from the overall analysis.

The image sets were divided into blocks of mixed-lists (intermixed negative and neutral images) and blocks of pure-lists (only negative images or only neutral images) for a between subjects design; with participants randomly assigned to either the mixed-list or pure-list condition. These image sets created 12 blocks for the mixed-list condition and 12 blocks for the pure-list (6 blocks of pure-neutral and 6 blocks of pure- neutral) condition. Each list contained 16 test images with an additional two buffer images (first and last image); hence each list contained a total of 18 images. The mixed-list blocks presented 8 test negative images and 8 test neutral images. All test images in the blocks were balanced for the presence of key non-emotional feature. Both the order of test images presented within each block and the order the blocks were presented were randomised across participants. The pure-list condition blocks were presented according to valence, so all the neutral image lists were presented together and all the negative image lists were presented together. The order of presenting either the neutral image blocks first or the negative image blocks first (and vice versa) was counterbalanced across participants.

5.2.3 Unique Number task

The study also presented a unique number task. This task was specifically developed for the purposes of this study, to provide an indirect measure of how attention grabbing the previous image has been. Behavioural performance measures of reaction time and accuracy on the number task would act as a measure, through which attention to the previous image could be quantified. As such, the number task was presented after every image in the study (see Figure 5.1). This task was developed as no other existing attention paradigm task was found, which would match the specific indirect measure of attention needs of this study. The number task was presented after every image in the study and it and required the participant to decide if the target number presented on the screen was higher or lower than the standard number ‘55’. The target number was displayed centrally on the screen in size 26ppt black font, against a white background. The target numbers ranged from 11-99 and were separated into 4 categories: easy low (EL: numbers ranging 11-40); easy high (EH: numbers ranging 70-99); hard low (HL: numbers ranging 41-54) and hard high (HH: numbers ranging 56-69). The number task posits numbers far away from the standard number ('55') will be easier to identify quickly, therefore categorised as easy; whereas, numbers closest to the standard number ('55') will be harder to identify quickly, therefore categorised as hard. All numbers below the standard number ('55') were categorised as low and all numbers above the standard number were categorised as high. The presentation of numbers was pseudo-randomised. There was a predefined list containing the order with which each of the number types was to be presented (i.e. which of the four categories the number comes from: EL,EH, HL, HH). Hence, when the list defined a number category, the computer would randomly generate any number within the appropriate number range for that category. For example if the list defined an EL number, a number was randomly generated from 11-40, likewise if the list defined a HH number, a random number from 56-69 was generated. This predefined list was the same for each participant and ran consecutively across the 12 blocks. Therefore, due to the counterbalancing and random presentation of the condition blocks, the numbers generated were always from the same categories for each participant, but they followed different image conditions. The number lists for each block were balanced and presented 14 easy category numbers (7 = EL; 7 = EH) and 4 hard category numbers (2 = HL; 2 = HH).

5.2.4 Procedure

Participants were first randomly assigned to either the mixed-list or pure-list condition. All subjects viewed the images on a 19" CRT screen upon which the stimuli were displayed, whilst sat in a chair approximately 70cm away from the screen. The images and the number task were displayed on screen using E-Prime 2.0 (Psychology Software Tolls, Pittsburgh, PA) and the accuracy of the synchronisation between the onset of the visual pictorial stimuli on the screen and the trigger received by the EEG system, was measured using BlackBox Toolkit (BlackBox Toolkit Ltd, York, UK) (see 2.2.3 Methods, Chapter 2). Each block started with instruction screens, reminding the participant of the number task and that the standard number was '55'. Each trial started with a variable fixation point (small black asterix) that was displayed centrally on a white screen for between 500-800ms. Using a variable latency is commonly employed in ERP studies (Pottage & Schaefer, 2012) and reduces anticipatory effects, which have been shown to be important in memory studies (Otten, Quayle, Akrami, Ditewigi, Rugg, 2006). After the fixation, the Image was displayed for 2000ms. The image was displayed for 2000ms rather than 1500ms as our previous studies used, as it is the same as the image duration used by Talmi, Luk et al., 2007 and Talmi & McGarry, 2012 and given the key hypothesis of the study aim to replicate findings of Talmi and colleagues (Talmi, Luk, et al., 2007; Talmi & McGarry, 2012), it makes this study more akin to their methods. Immediately after the image was displayed, the target number appeared on screen for up to 1500ms. Here participants were required to decide if the target number was higher or lower than the standard number '55' and respond as fast and as accurately as they could. Recording both the reaction time (RT) and accuracy for the number task response, allowed this study to obtain a measure of how attention grabbing the previous image and compare these results between conditions. Participants recorded their answers using the serial response box (Psychology Software Tools™), pressing number 1 if they thought the target number was lower and pressing number 2 if they thought the target number was higher. Once participants had made a decision on the number task, a blank white screen appeared for 2500ms minus the time taken to respond to the number task; so that the collective time taken to display the number task and the blank screen = 2500ms (see Figure 5.1). This procedure was repeated for the next trial, with a total of 18 trials in each block.

After each experimental block was finished, participants were required to complete a series of simple mental arithmetic questions, for 90 seconds. Participants were encouraged to answer accurately as many questions as they could within the 90 seconds. The questions were straight forward additions, subtractions, multiplications and divisions obtained from the internet, that participants filled out on paper, by hand. Once the 90 seconds were finished, participants were instructed to recall as accurately as they could, as many images they could remembered from the block they had just seen. Participants wrote the descriptions down by hand, on the paper provided using the following instructions:

"*You now have around 5 minutes to recall as many of the images that you have just seen. Please be exact and succinct in your descriptions, using only 3 or 4 main words for each picture, avoiding long sentences. If there are any ambiguous descriptions the experimenter will ask you to clarify at the end of the study. If you are unsure of any descriptions of the images, please do include them too, even if you feel you are just guessing.*"

Participants did have up to 5 minutes to freely recall the images, as a liberal criterion has been shown to improve the amount of accurate information retrieved during memory tests (Pottage & Schaefer, 2012; Wright, Gabbert, Memon & London, 2008); however, most participants did not need the full 5 minutes of recall time. Participants were well practised in all aspects of the task and performed 10 practice trials following the above format (displaying images similar to what the experiment would present). Subjects were given the opportunity to ask any questions, in order to familiarise themselves with the experimental procedure before beginning the recorded trails.

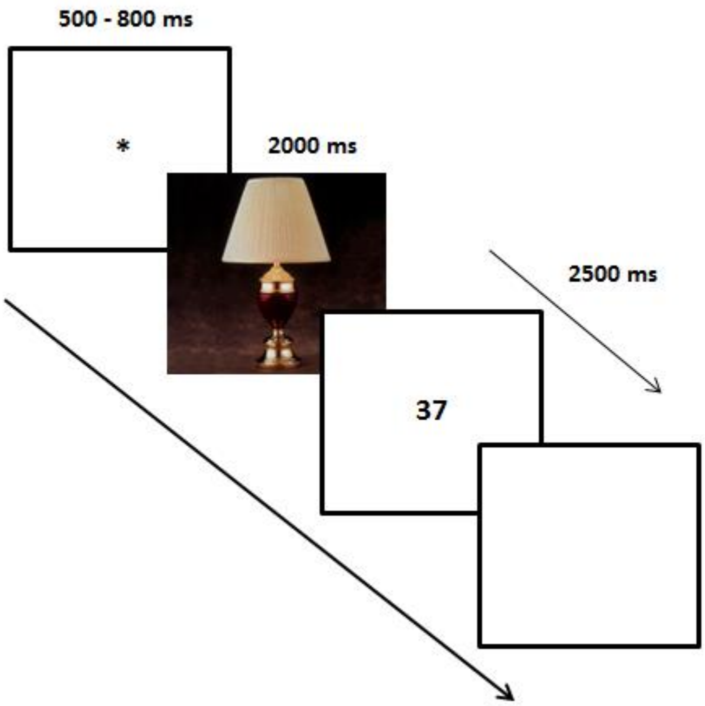

Figure 5.1: Schematic representation of the experimental trial procedure.

5.2.5 Memory Coding

The free recall descriptions from the participants were recoded independently by two coders, which follow methods established by previous research (Bradley, Greenwald, Petry & Lang, 1992; Talmi et al., 2007; Pottage & Schaefer, 2012). Only descriptions that could be identified as belonging to one particular image and could be differentiated from other images in the block were recorded as true memories, in order to prevent the possibility of false positives (false memories being encoded as true memories) being recorded. Following methods used by previous studies (Watts et al., 2014; Pottage & Schaefer, 2012) descriptions that were too vague to definitely allow concrete identification were deemed as false memories and discounted. Recoding the images was a straightforward process and similar to previous studies, was reflected in the high agreement between encoders (97.5%). Any disagreements that did occur between encoders were resolved by taking a conservative interpretation of the methodology outlined above.

5.2 6 Electrophysiological data recording and processing

The scalp electrophysiological activity (EEG) was recorded using a 64-channel cap (Waveguard, ANT Inc., Enschede, Netherlands) at a rate of 512 Hz (DC-138 Hz bandwidth), with an impedance < 20 kS. The EEG data was recorded using an average reference and then digitally converted to a linked mastoids reference. The EEG data was analysed using the ERP module of BESA 5.3 (MEGIS software GmbH, Grafelfing, Germany). All data were filtered offline (0.03-30 Hz), corrected for eye movements (Berg and Scherg, 1994), segmented into epochs between 100 ms before and 2000 ms after stimulus onset and then baseline corrected. For every channel, any epochs that had a difference between the maximum and minimum voltage amplitudes exceeding 120 μV or a maximum difference between two adjacent voltage points above 75 μV (after eye-movement artifact correction), were rejected.

ERP waveforms were created by averaging EEG data for remembered trials (items that were successfully recalled) and forgotten trials (items that were not recalled) separately for the lists of mixed-negative, mixed-neutral, pure-negative and pure-neutral images, resulting in six trial types: mixed-negative-remembered, mixed-negative-forgotten, mixed-neutral-remembered, mixed-neutral-forgotten, pure-negative-remembered and pure-negative-forgotten, pure-neutral-remembered, pure-neutral-forgotten. Following a criterion that is consistent with previous memory studies (Azimian-Faridani and Wilding, 2006; Kim, Vallesi, Picton & Tulving, 2009; Gruber and Otten, 2010; Galli, Wolpe & Otten, 2011; Padovani, Koenig, Eckstein & Perrig, 2013; Watts et al., 2014), any participants that recorded fewer than 12 artifact-free trials in any of the eight key conditions were excluded from the analysis. There were eight conditions in total (mixed-negative-remembered, mixed-negative-forgotten, mixed-neutral-remembered, mixed-neutral-forgotten, pure-negative-remembered and pure-negative-forgotten, pure-neutral-remembered, pure-neutral-forgotten) and the mean numbers of artifact-free trials per condition were: 36.6, 49.4, 24.7, 61.3, 37.05, 43.5, 33.9 and 47.45, respectively.

5.2.7 ERP data analysis

5.2.8 Selection of time windows and scalp locations

Based on a careful visual inspection of the data and the literature outlined in the introduction (see 5.1, Introduction) mean amplitudes were extracted from four main time windows to cover the full recorded epoch: 200-400, 400-800, 800-1500, 1500-2000ms. These time windows are consistent with the memory effects observed in our previous ERP studies, which examined mixed and pure-list conditions (see Chapters 2 and 3) and with the Dm effects observed in the literature. Analysing the 200-400ms time window will cover the early temporal effects associated with emotional stimuli that have been observed in similar time epochs in the literature (Otten et al., 2007; Duarte et al., 2004). These effects are thought to be reflecting the initial attentional and perceptual resources captured by emotional items, which in turn are driven by the motivational and evolutionary significance of emotional stimuli (Walker et al., 2011; Olofsson et al., 2008; Schupp et al., 2006). The next 400-800ms time window specifically targets the late positive potential (LPP), which is outlined in the literature as a component known to reflect activity relating to affective stimuli (Codispoti, De Cesarei & Ferrari, 2012). In addition, the 400-800ms covers the Dm effects often observed in this time window as outlined in the literature, which tend to begin ~400ms (Otten at al., 2001; Friedman & Trott, 2000; Fabiani et al., 1990). These Dm effects and the LPP correspond with effects associated with the engagement of post-perceptive attentional resources, observed in this same time window (Codispoti et al., 2007; Olofsson et al., 2008). The final two time windows (800-1500ms and 1500-2000ms) cover the effect often called the 'late LPP' or sustained slow waves. Effects have been observed spanning ~800-2000ms, at both frontal and posterior sites (Mangels et al., 2001; Otten & Rugg, 2001; Caplan et al., 2009; Kim et al., 2009), reflecting the modulation of working memory processes. This corresponds with the effects of the LPP being related to processes of working memory and specifically the manipulation of items in working memory to aid encoding (Schienle, Kochel & Leutgeb, 2011; Leutgeb, Schafer, Schienle, 2009; Olofsson et al., 2008; Schupp et al., 2006).

The findings of the previous chapters (see Chapters 2 and 3), which used ERP recordings and a mixed versus pure- list condition manipulation were used to guide the selection of scalp regions for this study as no other ERP study to our knowledge has used a mixed and pure-list manipulation using images. Therefore scalp regions were selected to fully encompass both anterior and posterior regions, spanning across left, midline and right electrode sites: left-anterior (F7, F5, F3, FT7, FC5, FC3), midline-anterior (F1, Fz, F2, FC1, FCz, FC2), right-anterior (F8, F6, F4, FT8, FC6, FC4); left-posterior (P7, P5, P3, TP7, CP5, CP3), midline-posterior (P1, P2, Pz, CP1, CP2, CPz) and right-posterior (P8, P6, P4, TP8, CP6, CP4). The data was averaged for single electrodes inside each ROI (Watts, et al., 2014; Schaefer et al., 2011; Walker et al., 2011; Curran, DeBuse & Leynes, 2006), in order to address familywise error in dense arrays of electrodes (Oken & Chiappa, 1986).

5.2.9 Statistical analysis

A mixed ANOVA was computed on the mean amplitude data from each of the time windows (200-400, 400-800, 800-1500, 1500-2000) using the following factors: Memory (Remembered vs

Forgotten items), Emotion (Negative vs Neutral), A-P (Anterior vs Posterior electrode sites) and Laterality (Left, Midline or Right electrode sites) and List (Mixed vs Pure list) added as a between subjects factor. Considering the hypothesis of the study, effects and interactions involving the factors of Memory, Emotion and List condition were preferentially targeted. It was expected that there would be significant main effect of Emotion and Memory across both mixed and pure-lists, reflecting the results previously found in the literature, which show that negative items have more positive going waveforms compared to neutral items and remembered items have more positive going waveforms than subsequently forgotten items (Watts et al., 2014). Furthermore, we expect the strongest Dm effects to be primarily found in the mixed-negative, pure-negative and pure-neutral condition as these are the conditions thought to benefit most from the additional factor of semantic relatedness. In accordance with the findings of Talmi, Luk et al., (2007), it is expected that mixed-list conditions will demonstrate the effects of distinctiveness reported previously in the literature (Watts et al., 2014), despite the added factor of sematic relatedness. Hence, it is expected that mixed-neutral items will have a reduced Dm effect, particularly across posterior sites. Any significant effects involving the factor of Memory were followed up with subsidiary analysis down to the level of Remembered vs Forgotten pairwise comparisons. For all analyses, partial eta-squares statistics were reported to provide estimates of effect-size and Greenhouse-Geisser corrections were used, with corrected p values reported where relevant.

5.3 Results

5.3.1 Behavioural Results

5.3.1.1 Recall

An Emotion X List mixed ANOVA was performed on the recall rates and revealed a main effect of Emotion [$F(1, 38) = 42.948$, $p < .001$, $\eta p^2 = .531$], which was driven by a higher level of recall of negative items (mixed-list mean negative recall = .43, SD = .07; pure-list mean negative recall = .44, SD = .12) compared to neutral items (mixed-list mean neutral recall = .29, SD = .11; pure-list mean negative recall = .40, SD = .08). This replicates the results of previous studies (See 2.3 and 3.3 Results, Chapters 2 and 3). There was also a significant main effect of List [$F(1, 38) = 5.29$, $p = .027$, $\eta p^2 = .12$], reflecting the lower level of neutral items recalled in the mixed-list condition compared to the pure-list condition (see Figure 5.2). This again is consistent with the results obtained in previous studies when using a mixed-list design (See 2.3 and 3.3 Results, Chapters 2 and 3). Crucially there was also a significant interaction between Emotion X List [$F(1, 38) = 15.39$, $p < .001$, $\eta p^2 = .288$]. To break down this interaction a priori comparisons were calculated to directly test the predictions of the hypotheses. A one-way ANOVA was conducted for each emotion type (negative and neutral) and revealed there was no significant main effect of List type for negative items (*ps* = .821); however as expected there was a significant effect of List type for neutral items [$F(1, 38) = 14.645$, $p < .001$, $\eta p^2 = .278$], which reflects the greater number of neutral items recalled in the pure compare to the mixed-list condition. This is consistent with the hypothesis, which purported there would be a reduced recall rate for neutral items in the mixed-list due to the relative distinctiveness of a mixed-list design. Planned contrasts were also calculated according to List type and revealed as expected, a significant effect of Emotion within the mixed-list condition ($t(19) = 6.497$, $p < 0.001$) reflecting the greater number of negative items recalled compared to the neutral items. Surprisingly however, the t-test on the pure-list condition also revealed a significant effect of Emotion ($t(19) = 2.193$, $p = .041$), which reflects the higher recall rate for pure-negative items compared to pure-neutral items (see Figure 5.2). This result is inconsistent with the hypothesis, which purported that due to the additional control of semantic relatedness there should be no difference between the recall rates of negative and neutral items when presented in a pure-list condition.

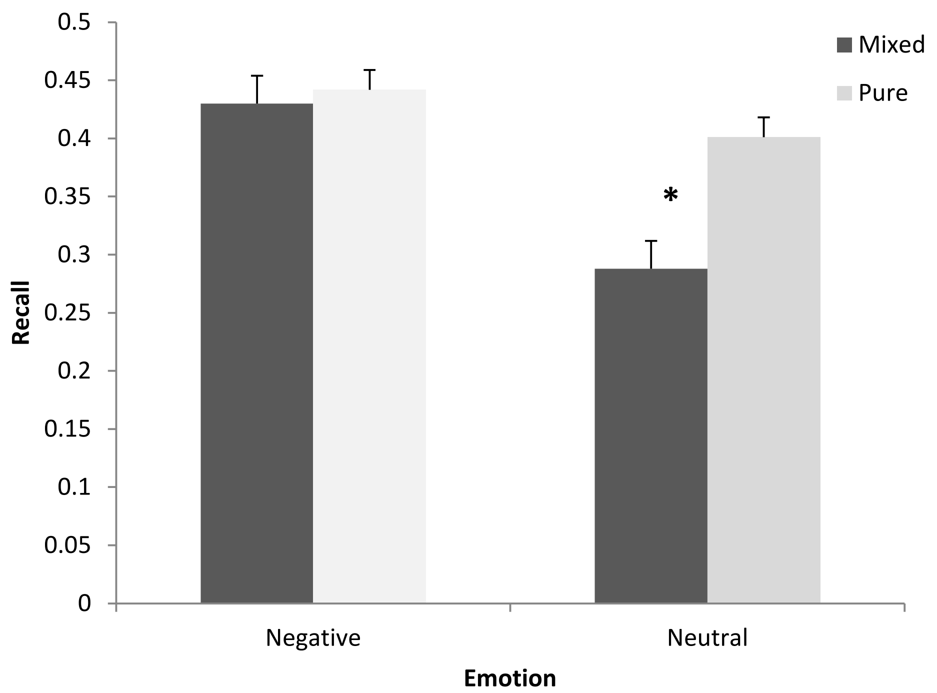

Figure 5.2: Mean recall rate by Emotion and List type. Error bars represent standard error of the mean.

5.3.1.2 Number task

Analysing the reaction time (RT) taken to respond to the number task using a mixed Emotion X List X Number-type (EL, EH, HL, HH) ANOVA revealed a significant main effect of Number- type. Subsidiary bonferroni pair-wise comparisons showed this effect was driven by a significantly longer time taken to respond to Hard numbers compared to Easy numbers; specifically the significant results occurred between the following conditions: EL and HL (*ps* < .0001), EL and HH (*ps* < .0001), EH and HL (*ps* < .0001), EL and HH (*ps* < .0001). There were no significant differences between EL and EH (*ps* = 1.0) and HL and HH (*ps* = .512). This result is in line with the design of the number task and hypothesis, which proposed it, would take longer to make a judgement and respond to Hard numbers as they are numerically closer to the target number. The mixed ANOVA revealed no significant main effect of Emotion [$F(1, 38) = 1.809$ $p = .187$, $\eta p^2 = .045$]. of List type [$F(1, 38) = .41$, $p = .526$, $\eta p^2 = .011$] and there were no interactions involving Number-type, which indicates there was no difference in the time taken to respond to the number task or different number types between negative and neutral items, or between mixed and pure-list conditions. There was however a significant interaction between Emotion and List [$F(1, 38) = 11.461$, $p < .01$, $\eta p^2 = .232$]. Breaking down this interaction by List type, the mixed-list condition revealed a significant effect of Emotion ($t(19) = 4.935$, $p < .001$), as the RT taken to respond to the number task following negative images (mean RT mixed negative =

724.48ms) was significantly longer than following neutral images (mean RT mixed neutral = 694ms). This is consistent with the hypothesis, which stated the RT taken to negative images would be longer than for neutral images. Computing the same t-tests for the pure-list condition however, did not produce a significant result (*ps* = .259); this is contrary to the hypothesis and shows overall there was no difference in the RT taken to respond to the number task between negative (mean RT pure negative = 689.16ms) and neutral (mean RT pure neutral = 702.31ms) images in the pure-list condition.

Analysing the accuracy of responses to the number task revealed overall an accuracy >96% across all four key conditions, indicating participants were engaging fully with the number task. A mixed Emotion X List ANOVA using the accuracy rates revealed a significant main effect of Emotion [$F(1, 38) = 5.284$, $p = .027$, $\eta p^2 = .122$]; this effect was driven by a higher overall accuracy for the number task following neutral items (mean accuracy mixed neutral = 98%; pure neutral = 97.6%) compared to negative items (mean accuracy mixed negative = 97.54%; pure negative= 96.3%), which is consistent with the hypothesis. Crucially however, there was no significant main effect of List type (*ps* > .20) and Emotion did not significantly interact with List type (*ps* > .20), showing that the patterns of accuracy did not differ between list conditions. For completeness and to ensure the difference in accuracy between negative and neutral items did not compromise the RT findings, paired samples t-tests were conducted to compare the accuracy between negative and neutral items, within each list condition. The results revealed no significant differences in the accuracy recorded to the number task between mixed-negative and mixed-neutral items (*ps* > .23). The results for the pure-list condition did show a trend for pure-neutral items to have a higher level of accuracy compared to the pure-negative condition, however overall this effect was not significant (*ps* =.66). These results therefore provide evidence to suggest the accuracy levels did not compromise the RT results obtained for the number task.

5.3.2 ERP Results

A visual inspection of the data overall, show that the emotion of negatively valenced items enhances the Dm effect across both the mixed and pure-list condition. A closer inspection of the waveforms shows the Dm effects for negative items have a predominantly fronto-central distribution starting ~250ms after image onset and sustained to around ~1100ms into the recorded epoch, which is irrespective of list type (see Figure 5.3.2). In contrast, the Dm effect for negative items in posterior regions is generally weaker with a shorter latency and a later ~500ms onset. The general Dm effect for neutral items is reduced across all electrode sites, compared to negative items in both the mixed and pure-list conditions. A closer inspection of the Dm effects for neutral items shows, not only is the Dm effect reduced, it also appears to be inverted across some sites; particularly for mixed-neutral items across posterior sites (see Figure 5.3).

The statistical analysis will test if the visual inspection which revealed a stronger Dm effect for negative items compared to neutral items and a cancellation of Dm activity for neutral-mixed items across posterior sites is reliable and test in what time window the Dm effects are strongest.

200-400

A mixed Emotion X Memory X A-P X Laterality X List ANOVA revealed a significant main effect of Emotion [$F(1, 38) = 20.425$, $p < .001$, $\eta p^2 = .35$], showing that negative items have an overall larger positivity compared to neutral items. There was however, no significant main effect of Memory ($F < 1$), which reflects the initial visual inspection of the data and the overall weaker Dm effect across the neutral conditions. There were also no main effects or interactions involving List type ($F < 1$), indicating there were no differences between the stimuli presented in the mixed or pure-list conditions. There were however two interesting interactions involving the key factors of Emotion and Memory. There was a two way Emotion X Memory interaction [$F(1, 38) = 6.06$, $p = .019$, $\eta p^2 = .137$], which demonstrates that the Dm effects differ in magnitude according to stimuli being negative or neutral. There was also a more complex interaction involving Emotion X Memory X A-P [$F(1, 38) = 5.729$, $p = .022$, $\eta p^2 = .131$]. This again supports the visual inspection of the data, which found the strongest Dm effects to have a more frontal or anterior distribution.

To elucidate these interactions a subsidiary Emotion X Memory ANOVA was computed separately for anterior and posterior regions. The results at posterior sites revealed a significant main effect of Emotion [$F(1, 39) = 6.633$, $p = .014$, $\eta p^2 = .145$], but no other significant effects. This is consistent with the effects observed above and reflects the more positive going waveforms for negative items compared to neutral items. In contrast, the Emotion X Memory ANOVA conducted across anterior sites revealed a significant main effects of both Emotion [$F(1, 39) = 23.006$, $p < .001$, $\eta p^2 = .371$] and Memory [$F(1, 39) = 4.316$, $p = .044$, $\eta p^2 = .10$]; this again is consistent with the effects found above. Crucially however, there was also a significant Emotion X Memory interaction at anterior sites [$F(1, 39) = 11.56$, $p = .002$, $\eta p^2 = .229$]. It was found this interaction was driven by significant effects of Memory for negative items across anterior regions [$F(1, 39) = 15.262$, $p < .001$, $\eta p^2 = .281$]; the same effect was not significant for neutral items across posterior sites ($F < 1$).

These results suggest there is a strong Dm effect present for negative items across anterior sites, in both list conditions; however the Dm effect is not present for negative items at posterior sites. There are no significant Dm effects for neutral items, across either list type.

400-800

Computing the same 5-way mixed ANOVA as in the previous time window, confirmed again a significant main of Emotion [$F(1, 38) = 34.21$, $p < .001$, $\eta p^2 = .474$]; reflecting the larger positivity for negative compared to neutral items. Similar to the previous time window there was no significant main effect of Memory (*ps* = .085). Although the Emotion X Memory X A-P interaction found in the previous window did not reach significance in this time window, there were was an interesting interaction involving the key factors with a significant Emotion x Memory X Laterality interaction [$F(1, 56) = 5.993$, $p = .009$, $\eta p^2 = .136$, Ɛ = .734]. There was also a significant interaction between Memory and AP [$F(1, 38) = 4.154$, $p = .049$, $\eta p^2 = .099$], reflecting the difference in the Dm effects at anterior and posterior sites.

To elucidate these interactions, subsidiary Memory X Laterality ANOVAs were computed separately at both anterior and posterior regions, for each Emotion type. This ANOVA at posterior sites for negative items revealed a significant interaction between Memory x Laterality [$F(1, 58) = 6.985$, $p = .004$, $\eta p^2 = .152$, Ɛ = .744]. This effects was found to be driven by a significant effect of Memory across Midline electrode sites [$F(1, 39) = 5.014$, $p = .031$, $\eta p^2 = .114$], but not at Left ($F < 1$) or Right ($F < 1$) electrode sites. In contrast, the Memory X Laterality ANOVA for neutral items at posterior sites only revealed a significant main effect of Laterality [$F(2, 72) = 3.521$, $p = .038$, $\eta p^2 = .083$, Ɛ = .929] and no other interaction.

The Memory X Laterality ANOVA for negative items across anterior regions revealed main effects of both Memory [$F(1, 39) = 14.88$, $p < .001$, $\eta p^2 = .26$] and Laterality [$F(2,75) = 4.532$, $p = .015$, $\eta p^2 = .104$, Ɛ = .960], which is consistent with the effects outline above. Crucially there was also a significant interaction between Memory X Laterality [$F(2, 75) = 6.414$, $p = .003$, $\eta p^2 = .141$, Ɛ = .964]. This interaction was driven by significant effects of Memory across all three Lateralities: Left (*ps* = .032), Midline (*ps* < .001) and Right (*ps* = .002) electrode sites. The same Memory x Laterality ANOVA was computed for neutral items across anterior sites, but did not reveal any significant effects.

These results reflect the findings of the previous time window, indicating the presence of a robust Dm effect for negative items, across both list types, at anterior sites. This time window also showed there was a significant Dm effect present at Midline sites, across posterior regions, for negative items. Similar to the previous time window, there were no reliable effects of Memory for neutral items, in either list type.

800-1500

Statistical analysis using the same mixed 5-way ANOVA of Emotion X Memory X A-P X Laterality X List revealed a significant main effect of Emotion [$F(1, 38) = 17.698$, $p < .001$, $\eta p^2 = .318$] and consistent with the previous time windows and studies, shows that negatively valenced items exhibit more positive going waveforms than neutral items. There was an interesting interaction involving some of the key factors, involving Memory X A-P X Laterality [$F(2, 65) = 4.988$, $p = .013$, $\eta p^2 = .116$, Ɛ = .858]. There were two further interactions that involved the key factors of, Memory X A-P [$F(1, 38) = 9.586$, $p = .004$, $\eta p^2 = .201$] and Emotion X Laterality [$F(2, 75) = 9.183$, $p < .001$, $\eta p^2 = .195$, Ɛ = .983]. These effects suggest there are differences in the Dm effect as anterior and posterior sites, as was found in the previous time windows; in addition, there are differences in the effects of Emotion depending on the Laterality of the electrode sites.

To break down these interactions, a subsidiary Memory X Laterality ANOVA was computed separately for anterior and posterior regions. The results for posterior regions revealed significant main effects of Laterality for both negative [$F(2, 57) = 5.752$, $p = .011$, $\eta p^2 = .129$, Ɛ = .725] and neutral [$F(2, 64) = 3.559$, $p = .043$, $\eta p^2 = .084$, Ɛ = .820] items. No other interactions were found for either negative or neutral items. The same ANOVA was computed at anterior regions for negative items and revealed significant main effects of both Memory [$F(1,39) = 8.949$, $p = .005$, $\eta p^2 = .187$] and Laterality [$F(2, 72) = 8.706$, $p = .001$, $\eta p^2 = .182$, Ɛ = .924], which is consistent with the effects outlined above. Importantly, there was also a significant interaction between Memory x Laterality [$F(2, 76) = 4.474$, $p = .015$, $\eta p^2 = .103$, Ɛ = .981]. This interaction was found to be driven by significant effects of Memory across the Midline (*ps* = .004) and Right (*ps* = .001) Lateralities for negative items at anterior sites. Similar to the previous time window, the Memory X Laterality ANOVA for neutral items at anterior sites did not reveal any significant results.

These results in general mirror the findings of the previous time window and demonstrate strong Dm effects for negative items, in both list types, across anterior regions. The Dm effect found at Midline sites, across posterior regions for negative items in the previous time window, is no longer significant here. There were no significant effects of memory for neutral items found in this time window.

800-1100 and 1100-1500

In light of the results observed in the previous time window, it was decided to break down the time window into two further sections (800-1100 and 1100-1500ms) and compute the same statistical analysis again. This method is akin to the analysis employed in the results of Chapter 3 (see 3.3

Results, Chapter 3). The initial visual inspection of the data in this present study observed the Dm effect of negative items ending ~1100ms, which is similar to the effects observed in the previous study whereby the negative pure-list Dm effect was reduced post ~1100ms (see 3.3 Results, Chapter 3). Furthermore, the visual inspection of the data also suggested a reverse of the Dm effect for mixed-neutral items starting around ~1100ms. Hence, breaking down the 800-1500ms time window will allow a more exact inspection of the negative Dm effect and the cancellation of the Dm effect for mixed-neutral items.

Computing the same general 5-way ANOVA at the 800-1100ms time window revealed a significant main effect of Emotion [$F(1, 38) = 22.311$, $p < .001$, $\eta p^2 = .37$], which is consistent with the main effects reported above and shows more positive going waveforms for negative items compared to neutral items. This time window also produced two significant interactions involving the key factors, Emotion X Memory [$F(2, 55) = 5.61$, $p = .012$, $\eta p^2 = .129$, $\mathcal{E} = .725$] and a Memory X A-P [$F(2, 55) = 5.61$, $p = .012$, $\eta p^2 = .129$, $\mathcal{E} = .725$] interaction. To elucidate these interactions a subsidiary ANOVA was computed using the factor of Memory, separately for anterior and posterior sites. The results for posterior regions revealed no significant effects of Memory for both negative [$F(1, 39) = 1.152$, $p = .290$, $\eta p^2 = .029$] and neutral items [$F(1, 39) = 1.123$, $p = .274$, $\eta p^2 = .031$]. It is worth noting that the Memory effect for negative items across the posterior regions appears weaker for than for neutral items; however this is because the Dm effect for neutral items has become inverted. The posterior neutral items have a reversed Dm effect with more positive going waveforms for forgotten compared to remembered items, whereas the posterior negative items exhibit a regular Dm effect with more positive going waveforms for remembered compared to forgotten items. The same ANOVA was computed for anterior sites and revealed a significant main effect of Memory for anterior negative items [$F(1, 39) = 9.9$, $p = .003$, $\eta p^2 = .202$]. Memory was not significant for anterior neutral items [$F(1, 39) = .458$, $p = .502$, $\eta p^2 = .012$].

Computing the same analysis on the later 1100-1500ms time window revealed similar to the previous time windows, a significant main effect of Emotion [$F(1, 38) = 13.81$, $p = .001$, $\eta p^2 = .267$]. There were also two complex interaction involving the key factors, a Memory X A-P X Laterality X List [$F(2, 68) = 4.395$, $p = .019$, $\eta p^2 = .104$, $\mathcal{E} = .899$] and Emotion X Memory X A-P X Laterality [$F(2, 72) = 4.073$, $p = .023$, $\eta p^2 = .0.097$, $\mathcal{E} = .949$] interaction. To breakdown these interactions a Memory X A-P X Laterality ANOVA was computed separately for each List-type and Emotion. The results for neutral items in the mixed-list condition revealed a significant Memory X A-P X Laterality interaction [$F(1, 23) = 6.281$, $p = .016$, $\eta p^2 = .248$, $\mathcal{E} = .596$]. To elucidate this interaction a subsidiary Memory X Laterality ANOVA was calculated separately for anterior and posterior sites. The ANOVA at anterior sites did not reveal any significant effects. However the same ANVOVA at posterior sites revealed a significant main effect of Memory for mixed-neutral items [$F(1,19) = 7.089$, $p = .015$, $\eta p^2 = .271$]; this was driven by significantly more positive going waveforms for forgotten compared to remembered items. The Memory X A-P X Laterality ANOVA conducted for neutral items in the pure-list condition did not reveal any significant effects (all *ps* > .15). The Memory X A-P X Laterality ANOVA was computed for the negative items and revealed a significant Memory X A-P interaction for both the mixed-negative [$F(1,19) = 10.928$, $p = .004$, $\eta p^2 = .365$] and pure-negative [$F(1,19) = 7.214$, $p = .015$, $\eta p^2 = .275$] conditions. No other interactions from the ANOVA were significant for either list-type. To breakdown these interactions an ANOVA with the factor of Memory was computed separately for anterior and posterior positions, for each list-type. The results revealed there were no significant effects of Memory for either list-type at anterior (mixed-negative, *ps* =.076; pure-negative, *ps* = .077) and posterior (mixed-negative, *ps* = .714; pure-negative, *ps* =.778) regions. It is also worth noting that in both the mixed and pure-list conditions, the negative items at posterior sites had more positive going waveforms for forgotten compared to remembered items, indicating a reversed Dm effect.

Taken together, these findings show the Dm effect for negative items is isolated to anterior regions and is robust through the 800-1100ms time window. However, post ~1100ms the Memory effect is no longer significant at anterior regions and is inverted over posterior regions; this suggests the Dm effect for all negative items across both list conditions has ended. Similar to previous time windows there are no reliable Dm effects for neutral items, across either list condition. Furthermore, these results suggest that post ~1100ms there is a significant cancellation of the Dm effect for mixed-neutral items, over posterior regions.

1500-2000ms

The analysis was completed on the final time window and the mixed 5-way ANOVA revealed a significant main effect of Emotion [$F(1, 38) = 4.165$, $p = .048$, $\eta p^2 = .099$]. The effect in this time window is not as strong as the previous time windows, however it does show negative items have consistently more positive going waveforms than neutral items, through the whole recorded epoch. There was no significant main effect of Memory ($F < 1$), but there was a complex interaction between Emotion X Memory X A-P X Laterality [$F(2, 70) = 3.342$, $p = .045$, $\eta p^2 = .081$, $\varepsilon = .919$].

To elucidate this interaction an Emotion X Memory X Laterality ANOVA was conducted separately for each anterior and posterior region. The results at anterior regions revealed a significant main effect of Emotion [$F(1, 39) = 5.269$, $p = .027$, $\eta p^2 = .119$], which is consistent with the effects observed above and reflects the more positive going waveforms for negative items compared to neutral items. No other effects from this ANOVA were significant. The results at posterior regions revealed a significant main effect of Laterality [$F(2,62) = 6.122$, $p = .007$, $\eta p^2 = .136$, $\mathcal{E} = .799$], which subsidiary bonferroni pairwise comparisons showed was driven by significantly more positive going waveforms for activity recorded along Midline electrode sites compared to Right electrode sites. This finding is also consistent with results observed in previous time windows. No other effects from the 3-way ANOVA were significant.

These results support the findings of the previous 1100-1500ms time window and suggest that the effects of memory for negative items observed in the earlier time windows are no longer present post ~1100ms.

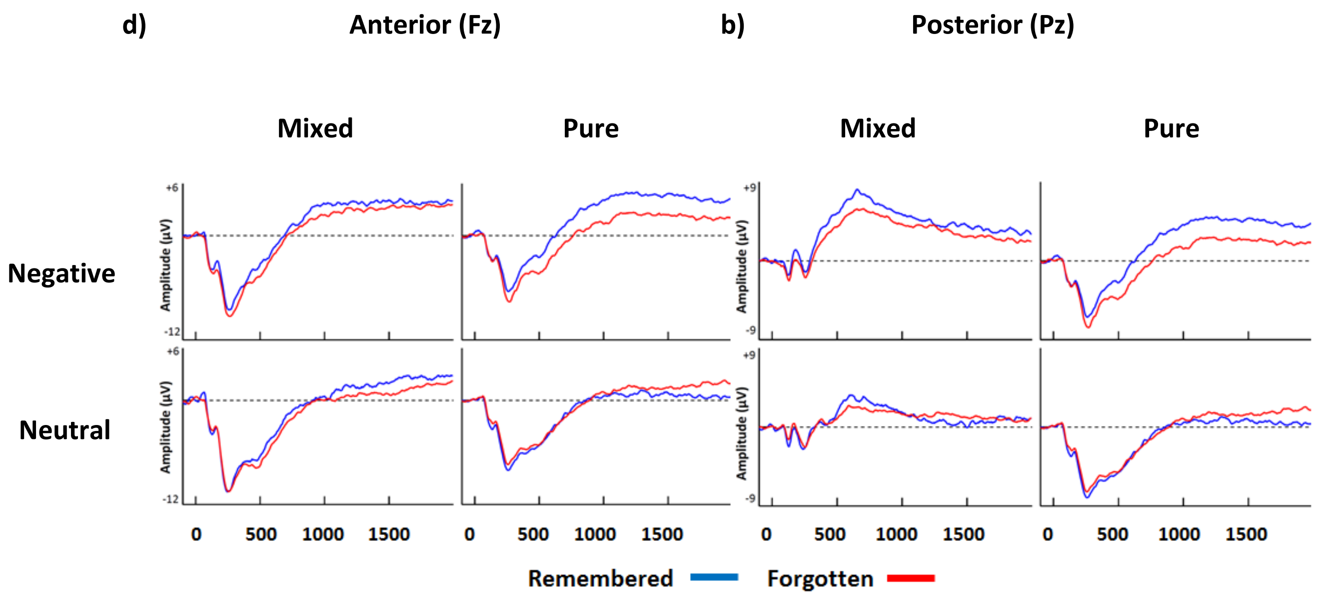

Figure 5.3: a) ERP waveforms plotted on electrode Fz for encoding-related activity separated according to subsequent memory (Remembered Vs. Forgotten items) and List type (Mixed Vs. Pure list items). Amplitude in microvolts (µV) is on the *y* axis and time in milliseconds is on the *x* axis. b) ERP waveforms plotted on electrode Pz for encoding-related activity separated according to subsequent memory (Remembered Vs. Forgotten items) and List type (Mixed Vs. Pure list items). Amplitude in microvolts (µV) is on the *y* axis and time in milliseconds is on the *x* axis.

In summary, these results suggest that negative items have an enhanced Dm effect, most prominently over anterior regions. This supports our hypothesis, which suggested there would be a robust Dm effect for negative items in both the mixed and pure-list condition; it also supports our behavioural data, which showed an increased recall rate for all negative items. The findings partially confirm the work of previous studies and our hypothesis in regards to the mixed-neutral condition, which showed a reduction of the Dm effect particularly at posterior sites. Moreover, this study found a significant cancellation of the Dm effect across posterior sites in the mixed-list condition. However this interpretation must be taken with caution as there was also a consistent reduction in the Dm effect of neutral items; this is an effect that was not observed in previous studies. The implications of this are discussed below.

5.4 Discussion

The findings of this present study overall support the hypothesis surrounding the mixed-list condition and the contribution of distinctiveness to the immediate EEM; with a significant difference between the amount of negative images compared to neutral images recalled in the mixed-list condition and a presence of EEM driven primarily by a reduction in the amount of neutral images recalled. This is also broadly reflected in the ERP data, which observed a robust Dm effect for mixed-negative items compared to a significant cancellation of the Dm effect for mixed-neutral items, across posterior sites. This evidence is consistent with the literature (Talmi, Luk et al., 2007; Watts et al., 2014) and the findings presented in Chapter 3 (see 3.4 Discussion, Chapter 3) and coupled with the behavioural reaction times (RT) to the attention task, provides support to the interpretation that distinctiveness exerts its influence in the immediate EEM though the preferential access to attentional and perceptual processing resources for mixed-negative items. The findings surrounding the pure-list conditions and the effects of relatedness however, do not provide support for the hypothesis guided by the research of Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012; Talmi, 2013). This study predicted that the recall rates across the pure-negative and pure-neutral condition would be comparable, as the items are now controlled for semantic relatedness. In contrast, this investigation found pure-negative items did have a mnemonic memory advantage over pure-neutral items, which is inconsistent with the evidence from the literature (Talmi, Luk et al., 2007; Talmi & McGarry, 2012). Furthermore, the RT data from the number task for the pure-list conditions, found the RT for both the pure-negative and pure-neutral items were comparable. This suggests that the EEM present in the pure-list condition cannot be accounted for by overt attentional processing. The implications of this are discussed in more detail below.

The results surrounding the factor of distinctiveness presented in this study provide support for the first hypothesis of the study, which posited that the EEM in the mixed-list condition would be driven by a significant reduction in the recall rates of the neutral items, compared to negative items; and are consistent with the evidence presented both in the literature (Watts et al., 2014; Talmi, Luk et al., 2013; Schmidt & Saari, 2002) and previous studies (see 3.4 Discussion, Chapter 3).This study found a significant reduction in the recall rates of the neutral items compared to the mixed negative items. Similar to previous work (Watts et al., 2014; Talmi, Luk et al., 2007; see 3.3 Results, Chapter 3), this study found a significant interaction between Emotion and List-type, driven by a reduction in the amount of mixed-neutral items recalled, compared to pure-neutral. These behavioural findings were also supported by the ERP data, which observed a robust Dm effect for mixed-negative items across anterior sites; whereas there were no reliable Dm effects for mixed-neutral items observed and moreover there was a significant reverse Dm effect found across posterior sites in later time windows, signifying a complete cancellation of the Dm effect for mixed-neutral items. In addition, the items presented in this study were controlled for semantic relatedness and in spite of this, the effects of distinctiveness and the memory advantage of emotional items were still observed in the mixed-list condition. This supports the findings of Talmi, Luk et al. (2007) and suggests that distinctiveness is a more important cognitive mediator in immediate EEM, than the factor of semantic relatedness.

Even with the additional control of semantic relatedness, the neutral items in a mixed-list condition were still not able to make use of this additional factor to help process the neutral stimuli, as the relative distinctiveness of the mixed-negative items preferentially captured the attentional and processing resources. This disrupted the encoding of mixed-neutral items and left little or no processing resources available, to utilise the semantic relatedness and successfully enhance encoding (Watts et al., 2014). Support for this interpretation also comes from the results recorded during the secondary number task in this study. The RT from the number task for the mixed-list condition found, as expected and consistent with the literature (Talmi, Schimmack, et al, 2007; Talmi & McGarry, 2012; Pottage & Schaefer, 2012), the latency to respond after a negative image was displayed, was significantly slower than if a neutral item was displayed. The high level of accuracy for the number task in the mixed-negative condition (> 97%) confirms that participants were fully engaged in the task and there was no trade-off between accuracy and RT, with participants responding with a longer RT to achieve a higher level of accuracy. These results demonstrates that there was a larger amount of attention and processing resources captured by the mixed-negative items, which meant fewer processing resources were available to be allocated to the number task, hence the latency was longer. Whereas, the mixed-neutral items did not capture the same level of attentional and processing resources, hence the number task following mixed-neutral items was able to mobilise a larger proportion of processing resources and complete the task faster.

Taken together, this evidence could provide support for the cognitive factor of distinctiveness leading to a two-step process of temporally sustained processing involving working memory, as suggested by Watts et al., (2014). The theory proposes a first step of relevance detection, in which early attentional processes are allocated preferentially to stimuli deemed as relevant to ongoing or future goals. Emotional stimuli have an evolutionary significance that can lead to them being deemed more task relevant (Ohman & Mineka, 2001; Frijda, 1986) and can provide clear signs to signify the need to prepare extraordinary resources (Schaefer & Gray, 2007; Schaefer et al., 2006). In this way, the first step would only be initiated by emotionally negative stimuli and not for neutral items (Watts et al., 2014). This interpretation is consistent with the effects observed in this present study. The Dm effect observed for mixed-negative items in the early 200-400ms time window overlaps with effects reported in the literature relating to the use of realistic affective image stimuli (Schupp et al., 2006), which are thought to reflect the stimulus driving properties of emotional stimuli, reflecting the motivational and evolutionary significance of negative items (Walker et al., 2011; Olofsson et al., 2008; Schupp et al., 2006). These early effects have been interpreted as reflecting the early attentional processes involved, which can aid encoding (Mangels et al., 2001; Duarte et al., 2004); and are consistent with the first stage of the two-step model, which calls processing resources to preferentially engage with emotional stimuli and disrupt the encoding of neutral items (Watts et al., 2014). More specifically the morphology of the Dm effects in the present study reflects a P3 like effect, which is an important ERP subcomponent widely thought to relate to attention and the processes involved in the initial stages of memory storage (Olofsson et al., 2008; Polich, 2007). In contrast to the findings of Watts et al., (2014) the P3 effect observed in this study is observed widely across frontal sites. However a frontal distributed P3 effect is thought to reflect stimulus driving effects that engage focal attentional resources and working memory mechanisms (Polich, 2007); hence, this interpretation is still largely consistent with the engagement of attention of task-related items and a call for resources (Schupp et al., 2006) outlined as the first stage of the two-step model (Watts et al., 2014).

The second phase of the two-step model is a causal effect of the first step being initiated and is thought to involve a sustained maintenance and manipulation of the visual information of the image in working memory, which can facilitate encoding (Watts et al., 2014). The morphology of the ERP effects observed in this study are consistent with this account and the second step of the two-stage model. Firstly, there was a significant Dm effect observed for mixed-negative items in the 400-800ms time window. This conforms to a LPP like effect that produces larger more positive going waveforms for negative items compared to neutral items, which has been observed globally across scalp sites across a similar latency (Codispoti et al., 2012: Codispoti et al., 2007); corresponding to the post-perceptual resources that are engaged to process emotional stimuli (Olofsson et al., 2008; Codispoti et al., 2007). Secondly there was a significant Dm effect for mixed-negative items observed in the later 800-1500ms time window, which overlaps with Dm effects reported in the literature at similar latencies (Mangels et al., 2001; Caplan et al., 2009) and more specifically with slow-waves reported in a similar 800-1500ms time window (Leutgeb et al., 2009; Schienle et al., 2011), also across frontal sites (Mangels et al., 2001; Kim, Vallesi, Picton & Tulving, 2009). The slow-wave observed in this study for mixed-negative items was not sustained through to the end of the recorded epoch

(2000ms) and came to an end ~1100ms; this is also a slightly shorter latency compared to the Dm effects reported in the study by Watts et al., (2014), which observed sustained effects up to ~1500ms. However this is not unusual, as Dm effects are known to temporally migrate (Otten et al., 2007; Paller & Wagner, 2002) and Dm effects observed in Chapter 3 also ended ~1100ms (see 3.3 Results, Chapter 3). Similar slow waves to those observed in this present study, have been reported in the literature and are thought to reflect a temporally sustained engagement of attention, which is involved in the maintenance and manipulation of information in working memory (Schupp et al., 2006; Olofsson et al., 2008; Watts et al., 2014). Hence both the LPP like effect and the slow-waves observed in this study correspond with the second phase of the two-step model; reflecting an increased attentional engagement for emotional stimuli, involving a maintenance and/or manipulation of the stimuli in working memory, which can aid the successful encoding of emotional items. These results therefore do offer some support the two-step model and account of distinctiveness in the immediate EEM; whereby the negative items initially preferentially capture attentional resources, which sparks a process of increased attentional engagement and manipulation in working memory that leads to successful encoding. In this way, negative items capture the majority of processing resources to the detriment and disruption of neutral items being encoded; hence a significantly higher recall rate for negative items and a significant reduction in the recall of neutral items.

Although the results outlined above generally support the two-step model (as described above), caution must be applied to this interpretation. While there was a significant reduction in Dm effects observed in the mixed-neutral condition, which has been attributed as being consistent with the two-step model of distinctiveness outlined above; there was also a significant reduction in the Dm effects observed in the pure-neutral condition. This finding is not wholly consistent with the two-step model or the findings from Chapter 2 and 3; as the two-step model posits that there should only be a significant reduction in the Dm effect, for mixed-neutral items. It is therefore likely that these results are reflecting the additional control of the factor semantic relatedness. One possible interpretation is that part of two-step of the model is determine by differences in inter-item relatedness; whereby, the first step of the model seeks to create thematic links between the items, to facilitate the encoding of the stimuli and engage the second, working memory step of the model, where these thematic links are maintained and manipulated to further benefit encoding processes. To create thematic links in the mixed-neutral condition is a more cognitively effortful process, as inherently negative items have a higher level of relatedness (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007). Additional cognitive effort is known to increase brain activity (Gray et al., 2005) and increased elaboration has been associated with larger Dm effects (Paller & Wagner, 2002, Otten et al, 2007; Caplan et al., 2009). Therefore it is likely, in previous studies (see Chapter 2 and 3) where the items were not controlled for semantic relatedness, the Dm effects observed in the mixed-neutral condition, reflected the increased cognitive effort needed to create thematic links to facilitate encoding. However, as the negative items outcompete the mixed-neutral items in this first step of the model (as negative items have inherently more thematic links; Talmi, Luk et al., 2007 and they capture more attentional processing resources; Schupp et al., 2006; Oloffson et al., 2008), the negative items have priority access to the second sequential step of the model and thus successfully encode more items. Similarly, the robust Dm effects observed in the pure-neutral condition of previous studies (see Chapters 2 and 3), could also reflect the additional cognitive effort employed to make inter-items links, to facilitate encoding processes. In this present study however, the negative and neutral items are matched for semantic relatedness. Hence, the additional cognitive effort required to create inter-item links in the mixed-neutral condition is no longer necessary as thematic links can be created more easily using the semantic relatedness of the items. This would be consistent with the lack of Dm effects observed in this study for the mixed-neutral condition. Similarly, the pure-neutral items in this study are also matched for relatedness; hence, there is no additional cognitive effort required to create thematic links, to facilitate encoding of the pure-neutral items. As such, the Dm effects in this present study for the pure-neutral items are also reduced; reflecting that there is no additional cognitive effort required to semantically link items, to facilitate the encoding process.

Hence, although the above evidence does provide some support for the two-step model outlined in previous studies (see 2.5 and 3.4 Discussion, Chapters 3 and 4), the evidence presented in this study suggests that parts of two-step model, are determine by inter-item relatedness. This therefore provides an additional part to the two-step model and explains how semantic relatedness can interact with distinctiveness in the immediate EEM.

Based on the evidence presented above there is one additional point to note, which requires further investigation. Specifically, looking at the morphology of the ERP results in this study reveals some slight differences compared to the effects observed previously (Watts et al., 2014). Although it is not unusual to observe the effects outlined above in frontal areas (Mangels et al., 2001; Polich, 2007; Kim et al., 2009), the LPP and slow-waves reported in previous studies were primarily reported at posterior sites (Watts et al., 2014; see 3.3 Results, Chapter 3). One possible explanation is that the mixed-negative items make use of their additional arousal level over neutral items, to aid encoding processes. Evidence from the literature shows that arousing items elicit larger and more positive going waveforms (Cuthbert, Schupp, Bradley, Birbaumer & Lang, 2000), particularly in the prefrontal cortex (PFC) where activity is sensitive to arousal (Dolcos, LaBar & Cabeza, 2004; LaBar & Cabeza, 2006); this is consistent with the larger Dm effect for negative arousing items across anterior sites, in this present study. It is widely accepted that the amygdala plays a crucial role in attending to arousing items at encoding (Phelps, 2004), which leads to a persistence of arousing items in memory (LaBar & Phelps, 1998). This processing of arousing items by the amygdala is thought to be a rapid and automatic response (LeDoux, 1995; Dolan & Vuilleumier 2003; Phelps, 2004) and activity in the amygdala can predict subsequent memory performance (Cahill et al., 1996; Sommer, Glascher, Moritz & Buchel, 2008). The robust Dm effect observed at anterior regions in this study could therefore reflect the subcortical activity of the amygdala (Friedman & Johnson, 2000), and the processing activity driven by the arousing nature of the negative stimuli. This interpretation would be supported by the arousal-biased competition (ABC) model proposed by Mather and Sutherland (2011). ABC proposes that arousal can modulate the strength of metal resources and enhance memory for those that dominate selective attentional resources. In this way the relative distinctiveness of negative items presented in a mixed-list condition creates an arousal based competition against the background of neutral items. This evokes bottom-up processing resources, as negative items are more perceptually engaging by 'popping out' amongst the neutral items; and top-down processes, as negative items are deemed more goal relevant due to their motivational and evolutionary significance (Schupp et al., 2006). In this way the arousal of negative items drives the selective attention and enhances bottom-up and top-down processing resources. Although this interpretation does fit the observed effects and accounts for a strong frontal Dm effect, it does not fully explain why previous studies did not find the same isolated frontal effects reflecting processing based on arousal, but also observed effects across posterior sites.

An alternative explanation that could account for the differences in the location of the Dm effect between this study and previous studies (see 2.3 and 3.3 Results, Chapters 2 and 3), is the controlled semantic relatedness of the stimuli used in this study. Talmi, et al. (2007; 2007; 2012) posit that controlling the semantic relatedness of images increases the likelihood of links forming between items during encoding, a process which aids encoding and subsequent recall. It has long been documented in the literature that a deeper semantic level of processing aids encoding (Craik & Lockhart, 1972). The added factor of semantic relatedness in this study means the negative items could be utilising this processing toll in tandem with the preferential capture of attention and the two-step model outlined above. It is possible during the second phase of the two-step model that the negative items are being maintained and manipulated in working memory as participants try to make links between stimuli, utilising the added semantic relatedness of the items. Although the neutral items try to utilise semantic relatedness as a processing tool, because the negative items have preferentially captured the initial attention on the first step of the model, they have prevented the processing of neutral items; the second step of the model occurs as a casual consequence of the first, hence the neutral items would rarely be afforded the opportunity to operate the second stage and manipulate items in working memory using the relatedness, to facilitate encoding. The morphology of the ERP effects obtained in this study also supports this semantic relatedness interpretation. It is widely reported in the literature that Dm effects are sensitive to levels of processing and semantic encoding (Paller, Kutas & Mayes, 1987; Weyerts, Tendolkar, Smid & Heinze, 1997; Wagner, Koutstaal & Schacter, 1999; Friedman & Johnson, 2000); with sustained effects reflecting elaborative encoding strategies having been reported starting ~300ms (Friedman et al., 1996) and Dm effects starting ~400ms (Otten & Rugg, 2001; Friedman & Trott, 2000), which are primarily observed across frontal/central sites (Weyerts et al., 1997; Friedman & Johnson, 2000; Friedman & Trott, 2000; Otten & Rugg, 2001). Consistent with these effects, the Dm effects for negative items observed in this present study also begin ~300ms and are sustained to ~1100ms, with a predominately frontal scalp location. The distribution of these effects overlap with other effects reported with a frontal scalp location, which reflects sustained potential and elaborative processing (Mangels et al., 2001). Taken together, these effects offer support to the notion that participants are using cognitive controlled elaborative processes and working memory resources to manipulate the negative stimuli, crucially creating semantic links between the items, which facilitates encoding. Utilising a deeper semantic level of encoding is primarily a process reflected at frontal sites, hence there is a notable absence of any Dm effects across posterior sites in this study; this is in comparison to previous studies (Watts et al., 2014) that did find posterior Dm effects but did not use semantically related stimuli. These effects would also support the above interpretation of the two-step model and the interaction of semantic relatedness; whereby the initial relevance detection step of the two-step model, is in some ways determine by differences in inter-item relatedness. Therefore it is likely that the stimuli utilise the semantic relatedness of the items as part of the two-step model; to facilitate the successful encoding of items. In mixed-list conditions however, although the items may be matched for relatedness, the negative items still preferentially capture more attentional resources (as reflected in the slower RT's to the number task; Schupp et al., 2006; Oloffson et al., 2008) and as such, are able to out-compete the mixed-neutral items to engage the second-step of the model; this results in more successfully encoded mixed-negative items and a reduced amount of encoded mixed-neutral items.

To fully investigate these effects of semantic relatedness, future studies could do a direct comparison between the ERP effects of stimuli controlled for semantic-relatedness and stimuli not controlled for relatedness. This would explicitly test if the processing of related stimuli is different to the processing of none related stimuli and if this process relies on the same frontal neural networks outline above. In addition, to test if participants are making use of the sematic relatedness of the items to aid encoding, future studies could test the memory for detail of items and see if this differs between items that have been semantically encoded and items that have not utilised semantic relatedness. The literature proposes encoding items semantically offers a deeper level of encoding, which leads to stronger, longer lasting and more elaborate memory traces (Craik & Lockhart, 1972). Measuring memory for detail would in some ways tap into the work done on recognition memory and memory strength, which differentiates between memories that are 'Remembered' versus 'Know' (Henson, Rugg, Shallice, Josephs & Dolan, 1999; Yonelinas, 2002; Kensinger & Corkin, 2004; Kensinger, Piguet, Krendl & Corkin, 2005; Schaefer et al., 2010). The Remember versus Know paradigm is widely thought to measure the qualitative differences in retrieved memories; whereby, 'Remembered' memories reflect a vivid recollection of the memory including contextual details of when it was learned, in contrast to 'Know' memories that are associated with a feeling of familiarity, but no contextual detail. Evidence has shown distinct neural differences between 'Remember' and 'Know' judgements for emotional stimuli (Schaefer et al., 2010), which suggests different sub-processes contribute to the depth of processing. Hence, future experiments using free recall could tap into these processes by analysing the level of contextual detail accompanying remembered items and utilise this method to test if there are differences in the quality of remembered semantically controlled stimuli compared to none related items.

The second factor this study investigated was the role that semantic relatedness plays, particularly in a pure-list condition. The results of this present study did not support the hypothesis, which posited that controlling the stimuli for semantic relatedness in a pure-list condition, would remove the memory advantage for negative items and recall would be equal across the two conditions (Talmi Luk et al., 2007; Talmi et al., 2012; Talmi, 2013). The results of this study found that using stimuli controlled for semantic relatedness did indeed significantly improve the recall rates, compared to previous studies that used non related items (recall rate of neutral items in this study compared to Chapter 2 *ps* = .001 and Chapter 3 *ps* = .0001; recall rates of negative items in this study compared to Chapter 2 *ps* = .017 and Chapter 3 *ps* = .0001). This does offer some support to Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi et al., 2012) and demonstrates that controlling stimuli for semantic relatedness does aid encoding processes and increases recall rates. However, the results of this present study found that although the recall rates were generally boosted for both pure-list conditions, there was still a mnemonic memory advantage for pure-negative items over pure-neutral items, with a significant difference in subsequent recall rates. This suggests that in contrast to previous work (Talmi, Luk et al., 2007; Talmi & McGarry, 2012), semantic relatedness alone is not sufficient to account for immediate EEM, when other factors such as distinctiveness (as stimuli presented in a pure-list condition) and attention (stimuli both presented in full attention conditions) are controlled for. Furthermore, the behavioural evidence from the number task showed that RT to the number task was equal, whether the task was preceded by the pure-negative or pure-neutral condition. This again is a surprising finding that does not support the hypothesis, as previous studies using semantically related stimuli have previously found a slower RT for negative items (Talmi, Schimmack et al., 2007). This suggests that the allocation of initial selective attentional resources were equal and both the pure-negative and pure-neutral items captured the same level of attention; despite pure-negative items ultimately having a significantly higher recall rate. Taking together the behavioural recall data and the RT results from the number task, this study suggests that controlling for semantic relatedness alone is unable to account for the immediate EEM and the mnemonic memory advantage for negative items cannot be attributed to an increased capture of selective attention resources at encoding. Hence, this study lends itself to an interpretation whereby, pure-negative items have privileged access to processing resources that can aid encoding, which neutral items are unable to utilise; these processes are above and beyond distinctiveness, semantic relatedness and an initial capture of selective attentional resources.

This interpretation is further supported by the ERP findings presented in this study. There was a robust Dm effect for pure-negative items, however as with the mixed-negative effects, these were primarily observed over frontal electrode sites. In contrast, there were no reliable Dm effects observed for pure-neutral items, again similar to the findings of the mixed-neutral condition. The strong Dm effects for pure-negative items, could reflect the privileged access to processing resources that neutral items are unable to utilise, which leads to the subsequent memory advantage for pure-negative items. The morphology of the Dm effects observed in the pure-negative condition are consistent with an interpretation that involves the role of arousal aiding encoding processes and enhancing subsequent memory; hence, it is possible arousal could be the driving force behind negative items having privileged access to a processing route that comparable neutral items cannot mobilise.

As outlined above and in Chapter 4 (see 4.4 Discussion, Chapter 4), arousal plays a crucial role in the long-term consolidation of emotional memories (McGaugh, 2000; 2004); it is widely accepted that the amygdala plays a crucial role in this process (Phelps, 2004; McGaugh, 2004), which over time leads to arousing items persisting for a long time in memory (LaBar & Phelps, 1998). Although it is thought, one way the amygdala processes arousing items is through an automatic capture of attention and subsequent encoding processes (Bradley, Greenwald, Petry & Lang, 1992; Olofsson et al., 2008), studies have shown amygdala activation at encoding can predict subsequent memory, even when a secondary task that taps into attentional resources is used (Kensinger & Corkin, 2004). Other evidence from the literature also found that the reaction time to a simple task presented after encoding arousing and non-arousing words, was equal irrespective of the arousal level of the to be encoded word, suggesting arousing items do not attract more selective attention (Sommer et al., 2008). This suggests the rapid and automatic response of the amygdala to arousing items (Phelps, 2004; Dolan et al., 2003) can occur outside of selective attentional processes. The amygdala is known to exert its affects for arousing items by modulating the consolidating activity in the medial temporal lobe and anterior parahippocampal areas (Dolcos, LaBar & Cabeza, 2004b; LaBar & Cabeza, 2006). These anterior regions also correspond to activity associated with arousing items, as activity in the prefrontal cortex has been shown to be sensitive to arousal and the Dm effects for arousing stimuli are greater in the prefrontal cortex (Dolcos et al., 2004; Kensinger & Corkin, 2004). Although the morphology of the Dm effects observed in this present study correspond with the primarily anterior Dm effects found for pure-negative items in this study, given the conclusions of the results found in Chapter 4 (see 4.4 Discussion, Chapter 4), it seems unlikely that arousal was able to immediately enhance memory here. Therefore it is more probable, that the Dm effects observed for pure-negative items here may have been partially reflecting the initial stages of the long-term arousal modulation of emotional memories (McGaugh, 2004). In this way, it would only be negative items that are able to utilise this unique arousal processing pathway, therefore adding to the explanation as to why there were no robust Dm effects in the pure-neutral condition, over anterior sites.

As mentioned the recall results for pure-negative items were significantly higher than recall rates obtained in two previous studies (see 2.3 and 3.3 Results, Chapter 2 and 3), which strongly indicates the semantic relatedness of the items have influenced encoding and contributed to the higher recall rates in subsequent memory. The processes involved in semantic processing and engaging in a deeper level of encoding are outlined in more detail above, but to summarise they are particularly sensitive to effects observed across frontal/central sites (Weyerts et al., 1997; Friedman & Johnson, 2000; Friedman & Trott, 2000; Otten & Rugg, 2001) and overlap with other frontal effects, which are known to reflect elaborative processing (Mangels et al., 2001). These effects correspond with the ERP morphology observed in this present study, which shows a robust Dm effect specifically over anterior sites and supports the interpretation that pure-negative items were utilising the semantic relatedness of the items to facilitate encoding. This interpretation fits the pattern of activity observed in this study, providing evidence that pure-negative condition utilised the semantic relatedness and arousal of items; both processes are associated with activity in frontal/central regions, which corresponds with the strong Dm effects across anterior scalp sites and absence of Dm effects across posterior sites (similar to the mixed-negative condition). Therefore even when semantic relatedness and attention are controlled for in pure-list conditions, negative items still have a mnemonic memory advantage over neutral items. As mentioned, although arousal could be affecting the observed neural activity, given the conclusions of Chapter 4 (see 4.4 Discussion, Chapter 4), it seems unlikely this translated into an immediate memory advantage there is an alternative explanation that has not been considered.

Talmi & McGarry (2012) propose the three key cognitive factors investigated by this present study (distinctiveness, relatedness and attention) provide a sufficient account of immediate EEM. However, evidence presented in this study suggested that relatedness, although it does have an effect at encoding, the effect is not as stable as previously presented (Talmi, Luk et al., 2007; Talmi et al., 2012) and cannot fully account for the immediate EEM, when other cognitive factors are controlled for; as there is still a mnemonic memory advantage for pure-negative items over pure-neutral items. The behavioural literature outlines a range of cognitive factors that can play a role in immediate EEM; therefore it is possible that it is one of these extraneous cognitive mediating factors, which has not been manipulated in this study that is contributing to the memory advantage for pure-negative items. One potential cognitive mediating factor that could be contributing to cognitive effects for negative images is emotional regulation (see 3.1 Introduction and 3.4 Discussion, Chapter 3 for more detail on emotional regulation). Emotional regulation refers to the influence emotions have on people and how people can influence which emotions they have, when they have them and how they can express and experience emotions (Gross, 1998). Research has shown how emotional regulation can have important cognitive consequences, particularly having a strong influence on memory (Richards & Gross, 2000). There are two main types of emotional regulation technique outlined in the literature: emotional reappraisal involves changing the way an emotional situation is construed to decrease the emotional impact; emotional suppression involves inhibiting the inner feelings the emotional situation creates and decreasing the outward expression of emotional experience (Gross, 2002). Emotional reappraisal is generally thought to be a more successful type of emotional regulation, but have less impact on memory; whereas emotional suppression is thought to have less impact at decreasing the emotional experience but can impair memory performance (Gross, 2002; Gross, Richard & John, 2006). Studies have shown that emotional regulation techniques generally utilise areas of the prefrontal cortex and amygdala (Goldin, McRae, Ramel & Gross, 2008; Ochsner & Gross, 2005; Ochsner, Bunge, Gross & Gabrieli, 2002); these areas overlap with the robust frontal Dm effects observed in the pure-negative condition and could indicate participants are utilising emotional regulation techniques. This evidence highlights the importance of emotional regulation and its potential cognitive implications as a mediating factor in immediate EEM. Therefore future studies should aim to include some measures of emotional regulation processes, as participants could be automatically engaging in regulation strategies, particularly in studies that use strongly emotional stimuli.

Another potential cognitive mediating factor not controlled for or manipulated in this study that could be influencing the results obtained is the way emotional stimuli and events tend to have a level of meaning-based processing. Emotional items tend to be processed more efficiently as people relate them to themselves and their personal history (Conway & Pleydell-Pearce, 2000; Schaefer & Philippot, 2005) and evidence from the literature suggests that this type of self-referential processing can also improve subsequent memory (Dewhurst & Conway, 1995). An imaging study from the literature revealed that this self-referential processing of negative stimuli activates regions of the medial prefrontal gyrus and the amygdala (Yoshimura et al., 2009). Further evidence has also implicated anterior regions of the cortical midline structure and areas of the prefrontal cortex in both self-referential emotional processing and self-referential memory processing (Northoff et al., 2006). The anterior regions associated with the self-referential emotional and memory processes overlap with the strong frontal Dm effects obtained for pure-negative items in this present study. This could therefore suggest some level of self-referential processing is occurring for pure-negative item, which could be improving subsequent memory. Again this highlights the need for future studies to investigate the role that other cognitive mediating factors play and how they explicitly exert their influence in the immediate EEM, to further research beyond the three key factors of distinctiveness, relatedness and attention (Talmi & McGarry, 2012).

The second point to emerge from the findings on relatedness that needs further discussion is that although either of the above interpretations (combination of semantic relatedness and arousal or another potential cognitive mediating factor) can account for the effects observed in the pure-negative condition, they do not account for the absence of any reliable Dm effects for pure-neutral items. As mentioned, similar to the pure-negative items, the pure-neutral items in this study have a higher recall rate than previous studies (see 2.3 and 3.3 Results, Chapter 2 and 3), which again strongly suggests that pure-neutral condition was utilising the semantic relatedness of the items, to facilitate encoding. Furthermore, the RT for the number task following pure-neutral images was comparable to pure-negative images and supports the findings of the study by Sommer et al., (2008), indicating that the differences in the observed Dm effects between the conditions, was not down to a selective attention advantage for pure-negative items that could aid encoding processes. As outlined above, activity sensitive to deeper levels of encoding and semantic relatedness tends to be observed across frontal/central sites (Weyerts et al., 1997; Friedman & Johnson, 2000; Friedman & Trott, 2000; Otten & Rugg, 2001). Therefore if the increased levels of encoding were down to the pure-neutral items mobilising the factor of semantic relatedness to facilitate encoding, it would be expected (similar to the pure-negative items) that there would be Dm activity observed across frontal/central electrode sites; yet there is a distinct lack of significant Dm effects for pure-neutral items in these regions. It is therefore likely, as explained above, that the previous Dm activity recorded for pure-neutral items (see 2.4 and 3.3 Results, Chapters 2 and 3) was a results of effortful cognitive processes, as individuals sought to create inter-item links between the neutral items, to facilitate encoding. However in this study, the pure-neutral items have a higher inherent level of relatedness, therefore creating inter-item links is no longer such a cognitively effortful process; hence, the overall Dm activity is reduced in this present study.

Moreover, it is not unusual to have an absence of any reliable Dm effects for pure-neutral conditions; the study in Chapter 4 also did not obtain any significant Dm effects for pure-neutral items (see 4.3 Results, Chapter 4). It is possible therefore also possible that this study is suffering from a lack of statistical power, due to a small sample size (N = 20). The previous studies that reported strong and reliable Dm effects in the pure-neutral condition both had considerably larger participant samples (Chapter 2, used 27 participants; Chapter 3, used 40 participants); in contrast to this present study and Chapter 4 (used 17 participants), which both had much smaller sample sizes and did not obtain any significant Dm effects. Future studies should aim to have larger sample sizes to fully establish if the absence of activity observed in this study is due to low statistical power. Another possibility is that the neural activity elicited during the semantic encoding of the pure-neutral items was not sufficient to translate into significant Dm effects. The ERP activity for neutral items is known to be smaller than those of negative items (Dolcos & Cabeza, 2002). In addition the low arousal level of the pure-neutral condition could contribute to smaller levels of activity. The pure-neutral condition is the lowest arousing condition of all four used and given prefrontal cortex activity is thought to be sensitive to arousal and greater for arousing items (Dolcos, LaBar & Cabeza, 2004a), this low level of arousal could have contributed to overall lower levels of activity obtained across frontal regions in this study. Therefore it is possible that even though the neutral items were utilising the semantic relatedness of the items to aid encoding, this activity was not strong or sufficient enough to be translated into significant Dm effects.

One final factor to consider is the themes around which the related stimuli were created. Talmi (Talmi, Luk et al., 2007; Talmi et al., 2012) devised the neutral stimuli around a central theme of domesticity, to ensure there were semantic links available through all the neutral items. Although the stimuli sets were equally rated for semantic relatedness, it is possible the negative stimuli set elicits a stronger level of activity when creating these semantic links around negative concepts such as violence; compared to the neutral stimuli set, which centres its links around every day domestic scenes. It is therefore possible that the links of domesticity were enough to aid encoding and enhance the processes of recall; however, the level of neural activity for pure-neutral items was not strong enough to evoke the strong frontal effects associated with deep elaborative processes and semantic encoding, as they did for pure-negative items. This interpretation is consistent with the preliminary findings of a similar ERP study conducted by Barnacle, Tsivilis & Talmi (in prep) that found no significant clusters of activity associated with the pure-neutral condition when using the same semantically related stimuli. To establish if the absence of reliable Dm effects on the pure-neutral condition are in some way a results of a confound due to the related stimuli set itself, other sets of neutral semantically related stimuli must be created and centred around a variety of themes. This would allow a more comprehensive study of relatedness and investigate the possibility that the semantic links created for negative items have neural differences to the semantic links created for neutral items.

The findings of using semantically related stimuli, when other cognitive factors such as distinctiveness and attention are controlled for have shown that semantic relatedness does boost overall recall performance and allows items to create semantic links at encoding, to enhance subsequent memory. However this study presents evidence to suggest the impact of semantic relatedness does not make the recall for pure-negative and pure-neutral items equal; therefore suggesting semantic relatedness is not as stable an influence in immediate EEM as the literature has proposed (Talmi, Luk et al., 2007; Sommer et al., 2008; Talmi et al., 2012). Hence, semantic relatedness cannot fully account for the immediate EEM in the absence of other cognitive factors, as Talmi (Talmi, Luk et al., 2007; Talmi & McGarry, 2012) theorised it would. This casts doubt over the conclusions posited in the study conducted by Talmi and McGarry (2012) that suggested the immediate EEM can be fully accounted for by three cognitive factors; distinctiveness, relatedness (or organisation) and attention. This study provides evidence demonstrating that when items are presented in a pure-list condition, even if they are controlled for semantic relatedness, there is still a mnemonic memory advantage for negative items; this suggests pure-negative items have privileged access to processing resources that neutral items are unable to utilise, which are beyond the resources of semantic relatedness and selective attention. This study offers two potential interpretations as to the processing resources negative items are able to uniquely mobilise; a combination of semantic relatedness and arousal processes or a cognitive mediating factor not accounted for in this present study. To fully establish which interpretation (if any) accounts for the unique process pure-negative items utilise further research is needed. Future studies could use imaging techniques to isolate the specific neural regions that semantic relatedness involves and see if this process is the same in both neutral and negative items. Moreover, imaging studies could shed light on the arousal interpretation and reveal if negative items are using this as a unique processing pathway; seeing if activity observed in the pure-negative condition overlaps with the known neural networks activated during the encoding of arousing items, which are not activated during the encoding of pure-neutral items. This study also highlights two areas of development in the paradigms used to investigate the cognitive factors responsible for the immediate EEM. Firstly, there is a need to develop a larger set of semantically related stimuli, which centre around more than one theme to ensure the effects in this study are not the results of confounds due to the stimuli used, but instead truly reflect the semantic processing of pure-neutral item. Secondly, future studies need to consider the role other potential cognitive mediating factors play in the immediate EEM, such as self-referential processing or emotional regulation techniques ; as this investigation has demonstrated the three key factors previously isolated by the literature (Talmi & McGarry, 2012) cannot fully account for immediate EEM.

The final factor investigated by this study was the role that attention pays in immediate EEM. The attention task used was a unique number judgement task, presented after encoding; the RT and accuracy recorded to the number task gives a measure of how attention grabbing the previous was. The behavioural results for the attention task obtained for all condition showed high levels of accuracy (>97%), therefore we can be confident participants were engaging in the number task and there were no compromises in accuracy as participants strived to react faster. More specifically the results revealed that the RT recorded in the mixed-list condition supported the hypothesis; the presentation of mixed-negative images resulted in a longer RT for the number task compared to the RT's recorded following mixed-neutral items. This is consistent with the literature that used divided versus full attention paradigms and found longer RT during negative image presentation compared to neutral image presentation (Talmi, Schimmack et al., 2007; Schaefer & Pottage, 2012; Talmi & McGarry, 2012). The longer RT for negative items is interpreted as reflecting the increased attentional resources negative stimuli capture, which leaves fewer processing resources available to engage in a concurrent or secondary task. This interpretation is consistent with the overall two-step theory of how distinctiveness plays a role in immediate EEM (Watts et al., 2014). In a mixed list condition the negative images have relative distinctiveness when presented against a background of neutral items. The two-step theory proposes that mixed-negative items preferentially capture the majority of the initial attentional and perceptual resources; this is supported by the longer RTs recorded during attention tasks associated with negative images. This initial capture of attention for negative items engages the second step of the model that involves the negative items being maintained and manipulated in working memory, which aids the encoding process. This ultimately leads to negative items preferentially being encoded, leaving fewer resources available to process neutral items; hence, an enhanced subsequent memory for negative items and reduced memory for neutral items. This provides evidence to show how important attention is to the immediate EEM and how the cognitive factor of distinctiveness relies on overt selective attentional resources to exert its influence on EEM.

The RT results for the pure-list condition however, showed the opposite pattern; it was found there was no significant difference in the RTs for the number task following either the pure-negative or pure-neutral condition. Although this does not support the hypothesis or the literature (Talmi, Schimmack et al., 2007; Pottage & Schaefer, 2012; Talmi & McGarry, 2012), this pattern of results has been observed in a study before, which used stimuli controlled for semantic relatedness, presented in a pure-list condition (Sommer et al., 2008). The results in this study therefore suggest that the overt selective attentional resources captured by the pure-negative and pure-neutral were equal, in contrast to the literature which suggests that negative items capture more selective attentional resources in pure-lists (Talmi, Schimmack et al., 2007). Despite the equal levels of semantic relatedness and selective attention captured between the pure negative and neutral conditions, there was still a memory advantage for negative items. This finding tentatively suggests that the mnemonic advantage for emotional items in a pure-list condition is beyond the effects of overt attentional resources. Hence, this suggests that the advantage for emotional items in the pure-list condition relies only on pre-attentive resources. This interpretation is in line with the results presented by Pottage et al., (2012) and Kensinger et al., (2004), who found that the memory advantage for arousing negative items was still observed under divided-attention conditions; where only pre-attentive resources are allowed to play a role.

Alternatively however, it could be suggested that the memory advantage for negative items in the pure-list condition occurs outside the influence of all attentional resources and that the pure-negative items had access to a unique set of processing resources unavailable to neutral items. This study suggests two possible interpretations of the unique processing resources that negative items could potentially mobilise. As explained in more detail above, it is possible that pure-negative items were utilising their higher arousal level to aid encoding processes. This interpretation is not novel as arousal has been implicated as playing a key role to the consolidation of emotional memories (McGaugh, 2004; LaBar & Cabeza, 2006); whereby the amygdala is involved in processing emotional stimuli and projects to other brain regions implicated in memory (hippocampus and prefrontal cortex), which facilitates encoding and forming long-lasting memories (LaBar & Cabeza, 2006). It has been suggested that high-arousing items may be processed differently during encoding, which aids their long term consolidation (Hamann, 2001), however studies from the literature have shown activity in the amygdala during encoding can predict memory, even after short delays (Hamann, 2001; Hamann & Mao, 2001; Sommer et al., 2008). Despite this, the evidence from the study conducted in Chapter 4 (see 4.4 Discussion, Chapter 4) suggests that arousal may enhance encoding related activity, but it is unable to enhance immediate memory. Therefore alternatively, the pure-negative items could be engaging in a processing route driven by a cognitive mediating factors not considered in this study. For example, negative items are known to be processes more self-referentially (Conway et al. 2000), which can also improve subsequent memory (Dewhurst et al., 1995). Self-referential processing of negative stimuli is known to associated with prefrontal areas (Yoshimura et al., 2009), which would correspond to the strong Dm effects in anterior regions, observed for pure-negative items in this study. Overall the evidence from the RTs in the pure conditions demonstrates that negative items have privileged access to a processing route, which can enhance memory; however, future studies are needed to establish if this unique processing route is related to the arousal level of the stimuli or another cognitive mediating factor, not manipulated in this study.

Although the attention task in this study provides strong evidence to suggest that the selective attentional resources captured in the pure-list condition are equal between negative and neutral items, this is contrary to what the literature outlines (Talmi, Schimmack et al., 2007; Pottage & Schaefer, 2012) and what this study predicted. Hence there are two points that require further consideration, as a result of these surprising findings. The first point to address is why the RTs recorded and hence, selective attentional resources allocated, were equal between the pure-negative and pure-neutral condition. There are some important differences between this study and the studies in the literature, which reported observing longer RT for negative items. For example the study by Pottage & Schaefer (2012) presented mixed-lists of images, which were not controlled for semantic relatedness. Therefore one line of speculation is that semantically related stimuli evoke a deeper level of semantic encoding that relies on selective attention; much in the same way distinctiveness relies on attention to fully exert its influence in EEM, it could be that relatedness needs to mobilise similar selective attentional resources in order to process to a deeper level. The literature outlines that the amount of attention devoted to a stimulus can dictate the depth to which it is processes (Craik & Lockhart, 1972) and as semantic processing is known to be an elaborative, deeper level of processing (Craik & Lockhart, 1972) it is therefore possible, to utilise the relatedness of the items at encoding requires more selective attention processes. Another difference between this study and the one conducted by Talmi, Schimmack et al., (2007) is that this study used a secondary attention task in the same visual modality as visually encoding images, rather than an auditory tone discrimination secondary task. As mentioned, it has been shown to fully tap into attentional resources the secondary attentional task must be in the same sensory modality (Schupp et al., 2008; Pottage & Schaefer, 2012). Therefore it is possible in the study conducted by Talmi, Schimmack et al., (2007) that the auditory discrimination task was not fully tapping into the selective processing of visual stimuli; meaning the RTs they recorded to the auditory discrimination task were not reflecting the selective attentional resources being used to process the related images. When these factors were controlled for in the study by Sommer et al., (2008), which used semantically related stimuli in a pure-list paradigm with a secondary task in the same sensory modality, it was found the RTs to the secondary task were also equal between pure-negative and pure-neutral items. In order to fully investigate if semantic relatedness processing does in some way require selective attentional processes (much in the same way as distinctiveness does) future studies are needed. This evidence however, highlights the need for any secondary attentional task to use the same sensory modality as the primary task, to ensure the attentional resources being tapped into fully reflect those being investigated.

The second point note from these findings concerns the nature of the secondary attention task itself. As mentioned, the attentional task used a unique and simple number discrimination task, which was presented after the image; rather than a classic divided versus full attention paradigm, which presents the secondary task at the same time as encoding the primary stimuli. Accuracy was high across all conditions (>97%) showing participants were fully engaging in the task and the results were valid. It is also not unusual to measure RT to a secondary task in this way to gage a measure of selective attention (Sommer et al., 2008). It is worth mentioning however that the results obtained to our attentional number task, were very similar to the RT data obtained by other studies that utilised a divided attention condition. The findings of a longer RT for negative items compared to neutral items is more similar to results obtained under divided attention conditions by Talmi, Schimmack et al., (2008) and Talmi and McGarry (2012); therefore it is possible that the number task used in this study, although not presented at the same time as encoding, did in some way divide the attention of participants. As participants were aware the number task appeared after every image and they were encouraged to remain as accurate as they could in their response, it is possible that some attention during image encoding the image was focused towards the impending number task. Although possible, this interpretation seems unlikely as the behavioural recall data remained high; during true divided attention tasks, there is an overall cost to subsequent recall and participants usually show lower recall rates across all conditions (Talmi, Schimmack et al., 2008; Talmi &

McGarry, 2012). This was not the case with the recall rates recorded in this study; they were in fact significantly higher than they had been in previous studies (see 2.3 and 3.3 Results, Chapter 3). This means we can be confident that the RT results obtained in this study were valid and reflective of a full attention condition.

Overall the behavioural results associated with the number task in this study provide evidence to support the literature and show that attention is a very important component to the immediate EEM (Talmi, Schimmack et al., 2008; Talmi & McGarry, 2012; Pottage & Schaefer 2012). Furthermore, this study suggests the unique number task developed as part of this study is a valid way to indirectly measure attention. This investigation suggests attention works both an independent factor and in conjunction with other cognitive factors such as distinctiveness and relatedness, to moderate the effects they have on immediate EEM; although future research is needed to fully establish the ways in which attention and semantic relatedness work together in EEM. The exact extent, to which attention as an independent factor plays a role in immediate EEM, is still an area of debate in the literature. Talmi and colleagues propose that attention only mediates EEM for emotionally positive images, but not emotionally negative images (Talmi, Schimmack et al., 2008); whereas Pottage & Schaefer (2012) found evidence to suggest that visual attention did play a significant role in the immediate EEM. This study provides tentative evidence to suggest that items in a mixed-list condition rely on overt selective attentional resources; whereas, items in a pure-list condition rely only on pre-attentive resources. To fully address this possibility and to resolve the discrepancy in the literature, future studies need to utilise a classic divided versus full attention paradigm in order to clearly manipulate attention influence. Crucially, the future studies need to ensure the secondary concurrent task taps into the same sensory modality as the primary task (Schupp et al., 2008). Other avenues of future research are also needed to establish how these conclusions can be extended to emotionally positive stimuli. This study focused on emotionally negative stimuli, but evidence has shown that the valence of emotional stimuli can have an impact upon the effects it has upon memory (Kensinger, 2009).

5.4.1 Conclusions

In summary this study has developed the research into the cognitive factors responsible for the immediate EEM and outlines three main conclusions surrounding the cognitive factors of distinctiveness, relatedness and attention. Firstly, the study has found distinctiveness plays an important role in immediate EEM, and its role is above that of semantic relatedness. This study provided evidence to support the interpretation that processes of distinctiveness partially rely on selective attentional resources and partially support the two-step theory outlined in Watts et al., (2014). The support for the two-step model is only partial, as there was a significant reduction in the Dm effects observed for the mixed-neutral condition, but also for the pure-neutral condition; a finding not wholly consistent with the two-step model. These results were therefore interpreted as reflecting the additional control of semantic relatedness; whereby it is likely that part of the two-step model relies on creating inter-item links between the stimuli, to facilitate encoding. Secondly, this study found evidence to support the literature in that adding the factor of semantic relatedness does indeed increase subsequent recall (Talmi, Luk et al., 2007; Talmi & McGarry, 2012). However this study provided evidence which is in contrast to the literature, as this investigation found that controlling for semantic relatedness alone (when other factors such as attention and distinctiveness are also controlled for) is not sufficient to fully account for the immediate EEM; as there was still a memory advantage for pure-negative items over pure-neutral items, even when they were equally semantically related. This suggests that pure-negative items have privileged access to a processing pathway that enhances memory, which pure-neutral items are unable to mobilise. This study speculates upon two potential processing routes that pure-negative items could have privileged access too: the first is arousal, whereby the pure-negative items could be processed in accordance with their higher arousal level in a route involving the amygdala and prefrontal brain regions associated with memory (Sommer et al., 2008); alternatively the pure-negative items could be making use of another cognitive mediating factor, not accounted for in this study, such as self-referential processing which is known to be associated with negative stimuli and enhance memory (Conway et al., 2000; Dewhurst et al., 1995). Lastly, this study provides evidence to support the interpretation that selective attentional processes are involved with the cognitive factor relative distinctiveness, as overt selective attentional resources were only found to influence the mixed-list condition. Furthermore, this study also offers evidence to suggest selective attentional processes could also be involved with semantic relatedness processing. In addition, the data surrounding the RTs to items in a pure-list condition, found no difference in the overt attentional resources obtained by pure-negative and pure-neutral items; this could tentatively suggest that items in the pure-list condition rely only on pre-attentive resources. In addition, this study speculates that this finding supports the interpretation that pure-negative items have privileged access to resources, which are beyond the effects of distinctiveness, semantic relatedness and selective attention processes. Future studies are needed to fully confirm some of the conclusions and interpretations presented in this study.

Chapter 6: Discussion

6.1 Chapter overview

This chapter summarises the findings of the work conducted in the previous four experimental chapters. The findings of these studies are discussed in terms of the overall aims of this thesis, with emphasis on the impact that each cognitive factor investigated has upon the immediate EEM. Conclusions are made about the overall role of distinctiveness, relatedness, attention and arousal in the immediate EEM. The strengths and limitations of this work as a whole are discussed and opportunities for future studies highlighted. The conclusions of these findings are also interpreted in terms of the real-world implications they have and how this work can be applied to other areas of research.

6.2 Summary of study findings

6.2.1 Chapter 2 summary

The study conducted in chapter 2 sought to investigate the role that distinctiveness plays in the immediate EEM. This study went beyond the traditional focus of investigating the impact that cognitive factors can have upon emotional stimuli, but investigated what effects that cognitive factors can have upon the encoding of neutral information too. As such, this investigation found that the cognitive factor of distinctiveness does indeed play a role in the immediate EEM. When items are presented in a mixed list condition (with intermixed emotional and neutral stimuli), the emotional items preferentially capture the attentional processing resources, which initiates a two-step process whereby emotional items are continually attended to and processed ultimately leading to them being successfully encoded in memory. As the emotional items capture these resources, it depletes the availability of processing resources available to the neutral items and as such, the neutral items do then not initiate the two-step process which leads to items being maintained in working memory and successfully encoded. This process explains how the distinctiveness of emotional items leads to them having more items successfully encoded into memory and how it influences the immediate EEM. Importantly however, this process also highlights the effects that distinctiveness has upon neutral items. As neutral items in a mixed list are competing for processing resources with negative items, this disrupts the encoding of neutral items and means they are not successfully encoded to the same level of negative items. Furthermore, this study demonstrated that the depletion of available attentional and working memory resources for neutral items in fact reduces the successful encoding of neutral items, when they are presented in a mixed list condition.

The ERP results of this investigation support the notion of a two-step model for successfully encoded emotional items. The early P3 like effects observed in this study are consistent with a relevance detection mechanism; this uses attentional resources to establish if a stimulus is relevant to on-going goals and thus requires the allocation of additional processing resources (Schupp et al., 2006; Polich, 2007). The later LPP ERP effects observed in this study are consistent with a second step to the model, which would involve temporally sustaining and manipulating the stimuli in working memory (Olofsson et al., 2008; Schupp et al., 2006); a process that facilitates encoding. These two steps are sequential, with the second step a causal consequence of the first step being engaged. As explained above this model is preferentially mobilised for negative items as negative stimuli are more likely to be considered task-relevant due to their evolutionary significance (Ohman et al., 2001) and provide clear signals that additional resources need to be mobilised (Schaefer et al., 2006; Schaefer & Gray, 2007; this leads to these items being successfully encoded into memory. However, these resources are disrupted for neutral items however and this leads to a reduced amount of neutral information being successfully encoded into memory.

This study has important conclusions for the research into the immediate EEM. The electrophysiological correlates associated with EEM have been identified in the literature (Otten et al., 2007; Dolcos & Cabeza, 2002; Palomba et al., 1997) and the behavioural literature has outlined several key cognitive factors responsible for immediate EEM (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2008; Talmi & McGarry, 2012). This study brings these two fields of research together and gives a functional meaning to these neural correlates of EEM, by linking them to the underlying cognitive factors known to influence immediate EEM. As such, this study provides evidence to show that distinctiveness plays a key role in immediate EEM. This study then further highlights the underlying neural processes associated with distinctiveness and provides a functional account of how distinctiveness exerts its influence in immediate EEM.

6.2.2 Chapter 3 summary

The study conducted in chapter 3 had the main aim of replicating the original findings demonstrated in chapter 2. In addition, the work presented in chapter 3 also investigated how various measures of individual differences could influence the interactions between emotion and memory. This study provides support for the work from chapter 2, confirming the important role that distinctiveness plays in immediate EEM and providing evidence that is consistent with the two-step model outlined above. Specifically this study replicated the behavioural results of chapter 2 and found a significantly reduced rate of recall for neutral items in the mixed list condition, compared to the pure list condition. This effect was mirrored in the ERP results with a significantly reduced Dm effect for neutral items, particularly across posterior regions. This study also found a significantly higher recall rate for negative items in the mixed list condition compared to the pure list condition, an effect not found in chapter 1. This however is not an unexpected finding as it supports the notion that the relative distinctiveness of negative items drives the immediate EEM, observed in a mixed list condition (Talmi, Luk et al., 2007; Schmidt, 1991). This effect was also mirrored in the ERP results with a consistent robust Dm effect for mixed negative items across all time windows. The morphology of the ERP effects observed in this study were consistent with the effects in the previous study (see chapter 2), thus offering further support to the two-step model. The early P3 like effects correspond with the first relevance detection step of the model, which determines the allocation of further attentional processing resources (Schupp et al., 2006). The LPP and late LPP effects observed post ~400ms are consistent with the second stage of the model, which reflects the temporally sustained manipulation and maintenance of information in working memory (Olofsson et al., 2008) that can facilitate successful encoding. Hence, this work fulfilled its primary aim and replicated the results presented in chapter 1.

The second aim of this study was to investigate how various measures of individual differences can influence the immediate EEM. Although in general there were no robust findings from the measures of individual differences, there were some selective interesting points to note. Working memory capacity (WMC) as measured by the OSPAN task, did not have any significant relationship with recall rates. However participants scored highly for WMC had a larger Dm effect for mixed neutral items in the early 200-400 time window, than low WMC individuals. This effect partially supported the hypothesis, whereby high WMC individuals have more flexible attentional processes (Bleckley et al., 2003) and thus can allocate attention to both negative and neutral items; hence a larger Dm effect for neutral items. However this Dm effect did not translate into an increased behavioural recall rate for mixed neutral items; therefore more research is needed to fully establish how tests of WMC can influence EEM. The measure of emotional regulation, contrary to the hypothesis, did not provide any strong behavioural recall evidence to suggest that emotional suppression can affect memory performance. An isolated ERP effect found a significant correlation between high suppression scoring individuals and a smaller Dm effect for mixed negative items, perhaps reflecting how emotional suppression can affect memory for negative items and providing partial support for the hypothesis. However, as this effect did not translate into clear behavioural recall effects, future research is needed to fully elucidate the impact of emotional regulation on EMM. The final two measures of individual differences (the Big Five Inventory and the BIS/BAS scale), similar to the previous measures, did not have any significant effects on behavioural recall performance. Although here were some isolated ERP effects (see 3.2.4. Discussion, Chapter 3 for more details) these were generally not consistent with the expectations derived from the literature. Therefore, more research is required to specifically test how personality dimensions interact with emotion and memory.

The work from this chapter provides crucial evidence to support the conclusions established in chapter 2. It confirms the role distinctiveness plays in EEM and how it can deplete the resources available for neutral items, reducing the Dm effect and subsequent recall rate. In addition, this study also provides support for the importance that the relative distinctiveness of mixed negative items has upon memory and how this specific cognitive attribute can drive the immediate EEM. Together these findings ultimately are consistent with the two-step model, which offers a functional account to the patterns of neural activity observed during a manipulation of distinctiveness and immediate EEM. Furthermore, this work investigated how measures of individual differences can influence emotion and memory. Although no robust conclusions were formed, this work offers an interesting starting point to directly test how personality can impact EEM.

6.2.3 Chapter 4 summary

The study conducted in chapter 4 had two main aims. Firstly, to establish the impact that arousal can have upon the immediate EEM, when there are no cognitive mediators available to enhance memory; and secondly to establish if pure-list negative conditions that contain intermixed levels of arousal, can behave much in the same way as a mixed-list condition. The results obtained to address the first aim found contrasting findings between the behavioural and ERP data. The recall rates presented in the behavioural data demonstrated no significant main effects of arousal. Although there were isolated significant paired sample t-tests between the high-arousal versus neutral condition and the low-arousal versus the neutral condition, overall these effects were not statistically reliable to inform our conclusions. As such the behavioural evidence suggested that the factor of arousal alone cannot influence the immediate EEM. The data presented in the ERP results however revealed contrary results, with consistent and reliable main effects of arousal observed through the full recorded epoch; with high-arousal the most positive going waveform, followed by the low-arousal condition and then the neutral condition. The Dm effects from the ERP results also revealed significant effects of Memory, predominately over Midline and Right electrode sites, for both high and low arousal items. In contrast however, the neutral items did not show any reliable Dm effects across any time window. Hence, results from the ERP data, contrary to the results of the behavioural data, suggest that arousal does have a significant impact on encoding related activity for the images presented in this study.

Overall these results present interest findings and were interpreted as providing support for both the cognitive mediating account of EEM (Talmi, Schimmack et al., 2007; Talmi, Luk et al., 2007) and the modulation hypothesis account of EEM. Support for the cognitive account of EEM (see 1.7 Immediate EEM, Chapter 1) comes from the behavioural results, which showed that in the absence of cognitive mediating factors, there was no immediate EEM. Hence, arousal alone is not sufficient to enhance the immediate emotional memory. However, the ERP results do show that arousal is having a significant effect on encoding processes, which offers support for the modulation hypothesis (McGaugh, 2000; McGaugh, 2004) and the long-term consolidation of emotional memories (see 1.6 EEM, Chapter 1). This work suggests that the encoding related activity recorded for this study reflects the initial engagement of the consolidation processes, which lead to a long-term emotional enhancement of memory. The Dm effects were predominately found along Midline and Right electrode sights, which is consistent with the literature that states activation of the right prefrontal cortex (Dolcos et al., 2004b) and the right amygdala (Cahill et al., 1996) predicts subsequent memory performance for negative stimuli. As these processes of consolidation are thought to take a period of days (McGaugh, 2004; Talmi, Luk et al., 2007), the activity recorded here is not sufficient to enhance immediate memory, as demonstrated in the behavioural recall results of this study. There is only an immediate enhancement of emotional memory, when cognitive mediating factors are engaged, as explained above. Future research is needed to fully test this working hypothesis. Future studies could incorporate a memory test after a period of delay, to test if the encoding related activity recorded here correlates with long-term memory performance; thus supporting the modulation hypothesis and the interpretations from this study.

The second aim of this study was to address the possibility that negative pure-list conditions with intermixed levels of arousal, can in some way act as a mixed list condition ('pseudo-mixed' list). The behavioural recall results revealed there to be a marginally significant difference between the recall rates of the low-arousal and neutral condition. Crucially however, there was no significant difference between the recall rates of the high-arousal and low-arousal condition. Both of these findings are in contrast to the behavioural results obtained in previous studies (see 2.4 and 3.3 Results, Chapter 2 and 3), which suggests that the true pure-list conditions, with no intermixed levels of arousal, presented in this study have in some way had an effect upon recall. Taking the above results together does indeed suggest that the previous pure-list conditions with intermixed levels of arousal, were acting as a 'pseudo-mixed' list. It is proposed that in the 'pseudo-mixed' list condition, the high-arousal items are preferentially capturing the processing resources, at the expense of the low-arousal items, which in turn reduces the recall rate of the low-arousal items. When the intermixed arousal levels are removed, as in the true pure-list conditions of this present study, this competition for resources is removed and the low-arousal recall rate is comparable to high-arousal. In this way, the pure-list conditions that present intermixed levels of arousal, act in much the same way as the mixed-list conditions do, with negative items preferentially capturing processing resources at the expense of neutral items.

The ERP results of this study also support this interpretation. Previous studies that presented pure-list conditions with intermixed levels of arousal, found no reliable Dm effects for the low-arousal condition (see 2.4.5, Results, Chapter 2). However this study found robust Dm effects for the low-arousal condition, across all time windows. This supports the above interpretation, whereby in the absence of the competition that intermixed levels of arousal create, the low-arousal items are able to make use of the processing resources available and successfully encode items; as reflected in the higher recall rate of low-arousal items in this study, compared to previous studies.

Overall, these results suggest that the intermixed levels of arousal used in the previous pure-negative conditions, were behaving much in the same way as mixed-list conditions; with high-arousal items preferentially accessing the processing resources, preventing the same level of successful encoding to low-arousal items. This finding is novel and presents important implications for future studies, which implement a mixed versus pure-list design.

6.2.4 Chapter 5 summary

The work in Chapter 5 aimed to address outstanding questions left from the previous chapters and specifically investigate the potential interactions of other cognitive mediating factors; specifically looking again at distinctiveness, but this time with the added cognitive factors of semantic relatedness and attention. The main conclusions of this study were three fold. Firstly, this study found supporting evidence for Chapter 2 and 3, in that distinctiveness plays a significant role in the immediate EEM. The behavioural results of this study found significantly more negative items were recalled in the mixed-list condition and this was primarily driven by a reduction in the amount of mixed-neutral items recalled. These findings were also supported by the ERP results, which observed a robust Dm effect for the mixed-negative items (primarily over anterior regions) and a significant reduction in the Dm effect for mixed-neutral items, which in some places observed a significant reduction in the Dm effect for mixed-neutral items. The RT results of the number study in the mixed-list condition also found significantly longer RTs, when the previous image was negative compared to neutral. Taken together these results initially seem to offer strong support for the two-step model as outlined by Watts et al., (2014). However, the ERP results observed in the pure-neutral condition also observed a significant reduction in the Dm effect; a finding that is not consistent with the two-step model. Hence, this study offers only partial support to the two-step model detailed in Chapters 2 and 3 (see 2.5 and 3.4 Discussion, Chapter 2 and 3). These contrasting findings were interpreted as reflecting the added factor of semantic relatedness. Whereby, mixed-neutral items previously had to exert cognitive effort to establish inter-item links between the stimuli, to facilitate encoding. This cognitive effort was reflected in Dm effects for mixed-neutral items, observed in the previous studies (see Chapters 2 and 3). However in this present study, the mixed-neutral items were matched with negative items for relatedness, hence there was no additional cognitive effort required to create inter-item links. This is reflected in the smaller and sometimes reversed Dm effects observed in this study for mixed-neutral items, as they no longer having to exert such levels of cognitive effort. It is therefore likely that the two-step model proposed in the literature (Watts et al., 2014) in some way determines the differences in inter-item relatedness as part of the two processes. Overall therefore, these results offer strong support for the significant role that distinctiveness plays in EEM. The RTs observed to the number task, confirm this process is likely to rely on overt attentional processes. Support for the two-step mechanism in this however is partial and based on the evidence provided in this study it is likely the two-step model also involves a process, whereby inter-item links are created between the stimuli to facilitate encoding. This is not an entirely novel interpretation, as this possibility was also suggested by Watts et al., (2014). Future studies however are needed to fully establish the links between sematic relatedness and distinctiveness and how relatedness could play a role in the two-step model.

Secondly, looking at the factor of semantic relatedness in the pure-list condition revealed that relatedness did significantly boost the recall in both the pure-negative and pure-neutral condition, compared to the results of previous studies (see 2.4 and 3.3 Results, Chapters 2 and 3). Despite this finding however, the behavioural results still revealed a mnemonic advantage for emotionally negative items over pure-neutral items. This is in contrast to the findings of Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012), who found that controlling for semantic relatedness abolished the EEM in pure-list conditions. The ERP results for the pure-list condition demonstrated a robust Dm effect for the pure-negative items, reflecting the higher recall rates for pure-negative items. However, despite the boost in recall performance for pure-neutral items, there were no reliable Dm effects across any time window. Taken together these results suggest that semantic relatedness alone, in the absence of other cognitive mediating factors such as distinctiveness and attention, is unable to fully account for immediate EEM. Furthermore the memory advantage for pure-negative items has been interpreted as providing evidence to suggest that pure-negative items are being processes in a unique way that neutral items are unable to mobilise. This study suggests this unique processing route could potentially involve a different cognitive mediating factor, not manipulated in this study; such as self-referential processing of negative items or emotional regulation. Further studies however will be needed to investigate this interpretation in more detail and assess if other cognitive factors can explain the memory advantage for pure-negative items.

The final cognitive mediating factor investigated was attention. The RT taken to respond to the number task was used as a measure to indicate how attention grabbing the previous image was. The results for the mixed-list condition revealed as expected, the RT taken to respond to the number task after a mixed-negative image was longer than the time taken following a mixed-neutral image. This is consistent with the literature (Talmi, Schimmack et al., 2007; Pottage & Schaefer, 2012) and suggests that attentional resources are primarily focused on processing and encoding the mixed-negative image and as such, the attentional resources are depleted when applied to another task. This depletion of resources then reduces the availability of resources available to apply to quickly process the number task. These findings, as mentioned, support the notion that the factor of distinctiveness intimately relies on overt selective attentional processing resources, which supports the two-step model outlined above. In contrast however, the RT results in the pure-list condition, showed no difference in the RT taken to respond following a pure-negative or pure-neutral item. This is in contrast to the expectations of the hypothesis and the literature (Talmi, Schimmack et al., 2007). These unique findings therefore tentatively suggest that the mnemonic advantage for pure-negative items over pure-neutral items is the result of pre-attentive processes. This interpretation is not novel; Pottage & Schaefer (2012) also found a memory advantage for pure-negative items under divided-attention condition, when only pre-attentive processing resources are thought to play a role. To investigate this possibility in more detail, future studies should directly manipulate attention in a full versus divided-attention paradigm. This will reveal if the way emotional items recruit attentional resources differs depending on whether they are presented in a mixed or pure-list condition.

Overall these results support the findings of Chapter 2 and 3, confirming the significant role that distinctiveness plays in the immediate EEM. Although these results do demonstrate that semantic relatedness can boost recall rate, the findings in this study suggest semantic relatedness alone is not sufficient to account for the immediate EEM, in the absence of other cognitive factors such as distinctiveness and attention. Attention was found to support the role of distinctiveness and these results also tentatively suggest that negative items in the pure-list condition rely on pre-attentive processes to facilitate encoding.

6.3 Impact of this work on the current literature

The work presented in Chapters 2, 3 and 5 offer support for the work conducted by Talmi and colleagues (Talmi, Luk et al., 2007; Talmi & McGarry, 2012); who proposed that distinctiveness plays a role as a cognitive mediating factor in EEM. The work in Chapter 3 found a significantly higher recall rate for items in the mixed negative condition, compared to the pure negative condition. The items in the mixed negative condition are relatively distinct (see 1.7.1 Distinctiveness, Chapter 1 for more details) and it is argued that this relative distinctiveness is one crucial factor that drives EEM (Schmidt, 1991; Dewhurst & Parry, 200; Talmi, Luk et al., 2007). Hence, a significantly higher recall rate for negative mixed items would strongly support this interpretation and suggest that it is the relative distinctiveness of the mixed negative items that has resulted in an increased subsequent memory performance. Moreover, the studies in Chapters 2 and 3 have gone further and advanced on the current literature to offer a functional account as to how relative distinctiveness exerts its influence in the immediate EEM, based on the electrophysiological correlates of encoding processes. Through this work, these studies have also investigated the impact that EEM has upon neutral information, a point that has received less attention from the field of cognitive neuroscience. We found that the encoding of neutral information in a mixed list condition is severely disrupted as it is outcompeted for processing resources by the negative items present. This effect is also incorporated into the functional account and is summarised by the proposed two-step model (see 2.5 and 3.4 Discussion, Chapters 2 and 3).

The work in Chapter 5 also found that the EEM in the mixed-list condition was in part driven by a reduction in the amount of mixed-neutral items recalled. This finding was further supported by the ERP data from Chapter 5, which observed a significant reduction in the Dm effect for mixed-neutral items. Although initially this finding also appears to support the two-step model, as mentioned above; we must be cautious in this conclusion as the results of Chapter 5 also observed a significant reduction in the Dm effects for the pure-neutral items. This is a finding which is not consistent with the two-step model and does not reflect the results obtained in the previous studies of Chapter 2 and 3. These surprising findings were interpreted as providing evidence to suggest that part of both the attentional and working memory processes of the two-step model are determine by differences in inter-item relatedness (see 5.4 Discussion, Chapter 5). Therefore the findings from Chapters 2, 3 and 5, support the literature and provide strong evidence for the significant role of distinctiveness in the immediate EEM. Moreover, the findings of Chapters 2 and 3 further the behavioural evidence of the literature and provide a functional cognitive account of distinctiveness (two-step model), and how it exerts its influence in immediate EEM. The findings of Chapter 5 then advance the initial interpretation of the two-step model, by suggesting that part of the attentional and working memory processing resources are determine by inter-item relatedness. However, future studies will be needed to fully examine if creating inter-item links is a fundamental part of the processing in the two-step model.

The work presented in Chapter 4 investigated the role arousal plays in the immediate EEM. Arousal has been strongly implicated as the driving force behind the modulation hypothesis, which has been used to explain the long-term enhancement of emotional memory (McGaugh, 2000; McGaugh, 2004); however, little research in the literature has investigated the role that arousal can have on emotional memory, immediately after encoding. A few studies in the literature have investigated the role of arousal and looks at the correlation between activity recorded ay the amygdala and immediate memory performance; however the results are conflicting, with one study observing no significant correlation (Hamann, Ely, Grafton & Kilts, 1999) and another study showing there is a significant correlation between amygdala activity recorded at encoding and recognition memory after a 15 minute delay (Hamann & Mao, 2002). The study (see Chapter 4) presented in this work suggests that arousal does not have a significant effect upon immediate memory free recall, when other cognitive factors are not allowed to play a role. The results showed no statistically reliable effects between the recall rates of the pure-low arousal and pure-high arousal condition, showing there is no impact of arousal upon immediate memory. This therefore supports the findings of Hamann et al., (1999); which also found no significant effects of arousal upon memory. Despite the fact there were no significant main effects of arousal upon memory recall; the ERP results did reveal a significant effect of arousal upon encoding related activity. This finding has been interpreted as offering support to the modulation hypothesis and long-term consolidation of emotional memories. It is suggested that these significant main effects of arousal upon encoding related activity, could reflect the initial stages of the amygdala activation and the start of the consolidation process of emotional memories (see 4.4 Discussion, Chapter 4). This finding is consistent with the study conducted by Hamann et al., (1999), which found significant correlation between amygdala activation and recognition memory, tested after a three week delay. Furthermore, this finding also supports the interpretation of EEM posited by Talmi, (2013), which states that the modulation theory and the cognitive mediating theory of EEM provide complimentary interpretations for both the immediate and long-term effects of EEM. Overall this shows how the study conducted in Chapter 4 offers support for an existing theory of emotional memory (modulation hypothesis; McGaugh, 2000; 2004) and in general furthers our understanding of what factors influence the immediate EEM. Despite these important conclusions there is still a discrepancy between the data presented here and the findings of Hamann et al., (2002). Therefore future studies are needed to fully address this contradiction and fully examine the notion that the influence of arousal upon the encoding related activity found here, do reflect the long-term process of consolidation.

The cognitive factor of semantic relatedness was investigated in the study conducted in Chapter 5. The findings did partially support the data from the literature, which suggested that controlling for semantic relatedness can enhance recall, making subsequent memory for both negative and neutral items equal (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012). The findings from our study did indeed demonstrate that when semantic relatedness is matched across negative and neutral items, recall is significantly boosted (compared to previous studies, see 2.4 and 3.3 Results, Chapters 2 and 3). This finding is also broadly consistent with the literature that suggests encoding items to a deeper (semantic level) can lead to a stronger memory (Craik & Lockhart, 1972); and allowing for a role of organisation, to create links between items at encoding, will facilitate memory (Hunt et al., 1993). However in contrast to the literature, the behavioural recall results of this study (see 5.3 Results, Chapter 5) still observed a significant memory advantage for pure-negative items; despite both negative and pure items being matched for semantic relatedness. This does not support the conclusions of Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012), who suggested that controlling for semantic relatedness can remove the EEM. This study found that semantic relatedness alone (in the absence of other cognitive mediating factors, such as distinctiveness or attention) is unable to account for the immediate EEM. This is an interesting finding and demonstrates how there is always a need to try and replicate findings, to ensure the conclusions are reliable. Furthermore, this study demonstrates that there is still a memory advantage for negative items, even when the cognitive factors of semantic relatedness, distinctiveness and overt selective attentional resources are controlled for. This again does not support the account of immediate EEM, which posits that relatedness, distinctiveness and attention provide a sufficient account of the factors involved in mediating the immediate EEM (Talmi & McGarry, 2012). The findings of our study have been interpreted as providing evidence to suggest that research needs to be focused on other potential cognitive mediating factors such as how emotional regulation affects the immediate EEM and how potentially the self-referential processing of emotional stimuli can influence the immediate EEM.

The final factor investigated by this work was the role that attention plays in the immediate EEM. The literature outlines how attention is critical to encoding emotional stimuli; with arousing items more likely to be attended too (Dolan et al., 2003) and encoded into memory (Kensinger, 2009). Key theories of emotional memory have centred on the role that attention plays in forming emotional memories (Easterbrook hypothesis, 1959; weapon focus effect, Loftus et al., 1987). Furthermore, the evidence presented in upon the role of distinctiveness provides strong evidence to suggest that attentional resources play a critical role in the two-step model (Watts et al., 2014). The behavioural evidence of RT in response to the number task presented in Chapter 5, strongly supported the above evidence and showed that attentional processing resources were consistently depleted for the number task, following a mixed-negative image compared to a mixed-neutral image. This behavioural finding is also consistent with RTs found in similar studies, which manipulated attention (Talmi, Schimmack et al., 2007). Generally this finding supports the notion that overt attentional resources are involved in immediate EEM (Talmi, Schimmack et al., 2007). However the findings in the pure-list condition, presented in Chapter 5, did not find a significantly longer RT to respond to the number task following a negative image compared to a neutral image; the RTs were comparable across both conditions. This is in contrast to the results found in the mixed-list condition and the effects outlined by the literature (Talmi, Schimmack et al., 2007). This effect was interpreted as demonstrating that the memory advantage for negative items in the pure-list condition relies on pre-attentive processes, rather than overt selective attentional processes. This interpretation is consistent with studies, which found a significant memory advantage for emotional items, even under divided attention conditions, when only pre-attentive processing resources are allowed to play a role (Kensinger & Corkin, 2004; Pottage & Schaefer, 2012). Although these findings as a whole are supported by evidence from the literature, the notion that emotional items in a mixed versus pure-list condition, rely on difference attentional processes is novel. Hence, future studies will be needed to fully address this possibility.

6.4 To what extent does distinctiveness play a role in the immediate EEM?

The evidence presented in this work (see Chapters 2, 3 and 5) strongly supports the behavioural evidence presented in the literature, which suggested that the cognitive factor of distinctiveness plays a significant role in the immediate EEM (Hunt & McDaniel, 1993; Schmidt, 2002; Talmi, Luk et al., 2007; Talmi & McGarry, 2012). The behavioural findings of the studies conducted in this work (see Chapters 2, 3 and 5) support the behavioural literature (Talmi, Luk et al., 2007; Talmi & McGarry, 2012), which found significantly more negative items were recalled in the mixed-list condition compared to the neutral items. Furthermore, these studies found this significant difference between the recall rates of mixed-negative and mixed-neutral items was driven by a significant reduction in the amount of subsequently remembered mixed-neutral items. Both these findings were also supported by the ERP data, which observed consistently large Dm effects for mixed-negative items from 200ms-1500ms after stimulus onset. In comparison, the mixed-neutral items observed consistent reductions in the Dm effect, particularly across posterior brain regions; moreover, the study in Chapter 5 (see 5.3 Results, Chapter 5) found a significant cancelation of the Dm effect for mixed-neutral items in a later 1100ms time window. Together the behavioural and ERP results were interpreted as suggesting distinctiveness involves two-steps of processing (Watts et al., 2014). The first step would involve a relevance detection mechanism, driven by attentional resources determining which stimuli require additional processing resources; followed by a second-step, which would involve maintaining and manipulating these focused stimuli in working memory, to facilitate encoding processes. This two-step process explains the consistent memory advantage for mixed-negative items and the reduction in the amount of mixed-neutral items encoded; as mixed-negative items are deemed more relevant due to their motivational and evolutionary significance (Ohman et al., 2001), the first step of the model is preferentially engaged for mixed-negative items. As a result of the sequential nature of the model, this then preferentially recruits the additional working memory resources to process the mixed-negative items; which ultimately then increases the likelihood of these items being successfully encoded into memory. Conversely, the preferential treatment for mixed-negative items means the processing resources are not able to be used on mixed-neutral items to the same level; as such, this reduces the memory effects for mixed-neutral items (Watts et al., 2014). Furthermore, the findings from Chapter 5 suggest that part of the attentional allocation and working memory processes (as defined in the two-step model), could involve creating inter-item links between the stimuli, to facilitate encoding. This interpretation would be consistent with the literature that suggests creating links to enhance semantic encoding, improves memory (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012; Talmi, 2013).

In addition, the work presented in Chapter 5 also suggests that the factor of distinctiveness has more impact on the immediate EEM, than semantic relatedness. This is because, even when the items were matched for semantic relatedness (as in the study, Chapter 5), the amount of neutral items recalled in mixed-list condition was similar to that of previous studies (see 2.4 and 3.3 Results, Chapters 2 and 3) where the stimuli were not matched for semantic relatedness. In the study conducted in Chapter 5, there was no boost in recall performance observed for mixed-neutral items due to matched semantic relatedness, as there was for pure-neutral items. This therefore suggests that the impact of distinctiveness to reduce the recall performance of mixed-neutral items was stronger than the impact of matched semantic relatedness to boost the recall performance of mixed-neutral items; hence, distinctiveness plays a more influential role in the immediate EEM, compared to the role of semantic relatedness.

Overall this work demonstrates that distinctiveness plays a significant role in the immediate EEM, and supports the behavioural evidence outlined in the literature (Hunt & McDaniel, 1993; Schmidt, 2002; Talmi, Luk et al., 2007; Talmi & McGarry, 2012). Furthermore, this work provides a functional cognitive account (in the two-step model) as to how distinctiveness exerts its influence in the immediate emotional enhancement of memory. Situations involving the real-life formation of emotional memories are more likely to occur in a ‘mixed-list’ condition; as a natural every-day environment is likely to contain a mix of non-salient and emotional features. As such, these findings are akin to how emotional memories are likely to be formed outside of a laboratory setting. Hence, these findings supporting the role of distinctiveness and the two-step model are important findings in the research of emotional memories and have essential implications to the real-life formation of emotional memories and the treatment to emotional memory disorders.

6.5 To what extent does relatedness play a role in the immediate EEM?

The conclusions based on the findings of the study presented in Chapter 5, suggest that semantic relatedness can play a significant role in the immediate EEM; when the items were matched for semantic relatedness, the overall recall rates were significantly increased, when compared to previous studies that did not match for semantic relatedness (see 5.4 Discussion, Chapter 5). This therefore supports the literature, which states that encoding items to a deeper semantic level can facilitate memory (Craik & Lockhart, 1972). Similarly, matching the items for semantic relatedness creates a means through which the items can be linked together; a method of organisation known to facilitate encoding processes (Hunt & McDaniel, 1993). The main body of literature that examines the role of semantic relatedness specifically upon immediate EEM comes from Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012). These studies suggested that controlling for semantic relatedness created a significant improvement to observed recall rates for both negative and neutral items; an effect also demonstrated in our study. In addition, the ERP data for the pure-negative items observed robust and consistent Dm effects, primarily across anterior regions. These effects are consistent with the literature, which reports ERP effects sensitive to semantic encoding and elaborative encoding processes are primarily observed over frontal scalp locations (Weyerts et al., 1997; Otten & Rugg, 2001; Friedman & Trott, 2000).

Although these findings do support a role for semantic relatedness in immediate EEM, the findings from our study (Chapter 5) do not fully support the conclusions from Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012), which suggested that semantic relatedness can fully account for immediate EEM. Previous studies (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) have shown when semantic relatedness is matched across negative and neutral items, there is no memory advantage for negative items and the recall rates are equal. In contrast however, the findings of our study (see 5.3 Results, Chapter 5) showed that even when items were matched for semantic relatedness, there was still a mnemonic memory advantage for pure-negative items, over pure-neutral items. This therefore suggests, contrary to the findings of Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012), semantic relatedness alone is unable to fully account for the immediate EEM. These findings were further supported by ERP data; as mentioned above, there was a robust Dm effect for pure-negative items, however there were no reliable Dm effects observed for the pure-neutral condition, despite the improved recall rates. Furthermore, there were no significant differences in the RT data for the number task, across both the pure-negative and pure-neutral conditions; suggesting this difference in ERP effects is beyond the effects of overt selective attentional resources. These effects have been interpreted as demonstrating that pure-negative items are utilising a unique processing route (as demonstrated by robust Dm effects) that pure-neutral items are unable to mobilise. One possible processing route suggested is that pure-negative items could be using a cognitive mediating factor such as emotional regulation or self-referential processing (see 5.4 Discussion, Chapter 5 for more details).

One final point to consider in the role that semantic relatedness plays in the immediate EEM, is how is can interact with other cognitive factors, such as distinctiveness. The results surrounding the mixed-list condition presented in Chapter 5, tentatively suggest that forming inter-item links between items, may in some way be part of the of the processing steps involved in the two-step model. Creating inter-item links between stimuli is known to improve encoding (Craik & Lockhart, 1972; Hunt et al., 1993) and it has been suggested that this process is easier for negative items, as they inherently have a higher level of semantic relatedness (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012). Therefore it is possible that creating inter-item links between stimuli could be part of the maintenance and manipulation processing in working memory, as suggested in the two-step model (Watts et al., 2014); and this process is easier to complete for negative items, hence facilitating the encoding of negative items and enhancing the subsequent memory for negative items. Future studies however will be needed to fully examine this possibility.

Overall, the above data does support the interpretation that semantic relatedness plays a role in the immediate EEM and can improve overall recall rates for both negative and neutral items; with the ERP effects for pure-negative items also reflecting that semantic processing was taking place. However, unlike the literature proposes (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012; Talmi 2013), our findings suggest that semantic relatedness alone, is unable to fully account for the immediate EEM. Hence, although semantic relatedness can facilitate encoding processes and improve subsequent memory recall rates; as a cognitive mediating factor presented alone, it is unable to play a significant role and fully account for the immediate EEM.

6.6 To what extent does attention play a role in the immediate EEM?

Attention has been shown to be a very important factor in emotion and memory interactions (Easterbrook, 1959; Christianson & Loftus, 1989; Fredrickson et al., 2005; Kensinger et al., 2006; Gable et al., 2008); with the literature suggesting under certain conditions, attention has the ability to both narrow memory for peripheral details (Gable et al., 2008) and broaden memory for details (Fredrickson et al., 2005). The allocation of attention is needed so organisms can ovoid sensory overload and decide what stimuli require additional processing and what can be ignored (Eysenck & Keane, 2005). As such, items that are arousing are more likely to be attended to (Dolan et al., 2003) and thus encoded into memory (Kensinger, 2009). Attention has been implicated in the literature as being an important cognitive mediating factor in the immediate EEM (Talmi, Schimmack et al., 2007; Talmi et al., 2008; Talmi & McGarry, 2012; Pottage et al., 2012). Furthermore, studies in this work have implicated attention as playing a key role in the factor of distinctiveness; it is suggested the relevance detection mechanism of the two-step model relies on the allocation of attentional resources to facilitate memory encoding processes (see 2.5 and 3.4 Discussion, Chapters 2 and 3).

The study conducted in Chapter 5 studied the role attention can play in the immediate EEM. Although this work did not directly manipulated attention (in the classic divided versus full attention, paradigms), the study devised a unique number paradigm to act as an indirect behavioural measure of attention; performance measures recorded (RT and accuracy) to the number task after every image were used as an index to measure how much the previous image depleted attentional resources, and as such provide a measure as to how 'attention grabbing' the previous image was. The results revealed RTs were longer following the presentation of a mixed-negative item, compared to a mixed-neutral item. This finding, coupled with the enhanced subsequent memory performance for mixed-negative items compared to mixed-neutral items, supports the above interpretation;

whereby, the allocation of overt selective attentional resources has a direct effect upon the subsequent memory and this the immediate EEM. Furthermore, these findings also support the role that attention plays in the factor of distinctiveness; as mixed-negative items are benefitted by both the factors of relative distinctiveness and attention, it supports the notion that these factors interact together to contribute to the immediate memory advantage for mixed-negative items.

In contrast however, the data presented in Chapter 5 for the pure-list conditions did not observe a significant difference in the RTs taken to respond to the number task, following the pure-negative or pure-neutral item. This finding does not support the above interpretation that posits overt attentional resources are needed to support the memory enhancement for emotional items (Talmi, et al., 2008). However, this results has been observed before in the literature, when using a pure-list condition (Sommer et al., 2008) and could suggest that negative emotional items rely on pre-attentive resources (Pottage et al., 2012) or that emotional items have an additional direct effect on memory, beyond the effects of over attentional processes (Talmi, Schimmack et al., 2007).

Overall these results support the notion that attention plays a significant role in the immediate EEM; specifically in mixed-list conditions. In addition, the evidence suggests that attention can play a role both as an individual factor and in conjunction with other cognitive mediating factors, such as distinctiveness. However, this interpretation is not compatible with the evidence that is presented in the pure-list condition; which tentatively suggests that emotionally negative items can have a direct effect upon memory. Future research is necessary to identify exactly what these processes could be. The role of attention in the formation of emotional memories is therefore essential in a mixed-list environment. As mentioned above a mixed-list environment is akin to the type of real-lift situation, in which emotional memories are encoded. Hence, research conducted to examine precisely how the factor attention influences emotional memory interactions could have important implications in treating emotional memory disorders.

6.7 To what extent does arousal play a role in the immediate EEM?

Arousal is strongly implicated in the literature as the driving force behind the long-term consolidation of emotional memories (Hamann, 2001; McGaugh, 2004). However little is known about the exact impact arousal can have upon the immediate EEM, in the absence of other memory enhancing cognitive mediating factors. The study presented in Chapter 4 suggests that arousal alone is not sufficient to enhance immediate emotional memory and as such, does not play a significant role in the immediate EEM. The behavioural recall rates found no significant main effect of arousal, suggesting the arousal level had no effect upon immediate memory. In contrast however, the ERP results did reveal a consistent main effect of arousal, with high-arousal items having the most positive going waveforms and the most robust Dm effect. This evidence may initially seem conflicting, however it has been interpreted as providing support for both the cognitive mediating account of EEM and the modulation hypothesis (see 6.2.3 Chapter 4 summary, Chapter 6).

Therefore, the conclusions surrounding the impact of arousal on EMM are twofold. Firstly, the evidence of this work suggests that arousal alone is not sufficient to enhance the immediate effects of emotional memory. Arousal however, does have an impact on the recorded encoded related activity which has been interpreted as reflecting the initial stages of the long-term consolidation of emotional memories. Hence, the role of arousal itself as a factor, in the absence of other cognitive mediating factors, is unable to have a significant impact on the formation of immediate emotional memories and thus, the immediate EEM.

6.8 The immediate EEM

It is well documented in the literature that emotions are adaptive responses, allowing organisms to safely interact with their environment (Ekman, 1992a; LeDoux, 1995; Hamann, 2001; Phelps, 2006). From an evolutionary perspective, emotional responses are signalling to the organism that the stimulus is likely to have both immediate and future relevance (Hamann, 2001). Therefore by extension, it has been shown that emotional memory systems may have evolved to specifically retain information relevant to survival (Nairne, Thompson & Pandirada, 2007). For example, it would enhance an organism's chance of survival to remember to location of a food source, or to avoid a location where a predator lives. The evidence for emotional memory systems presented by the literature suggest there are two distinct parts to the formation of emotional memories; the immediate memory enhancement, observed at short delays (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) and the long-term storage of stable emotional memories, formed through a process of consolidation (Cahill & McGaugh, 1998; McGaugh, 2000; 2004).

The immediate enhancement of emotional memory is thought to rely on cognitive mediating factors (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2008; Talmi & McGarry, 2012; Talmi, 2013) and the studies presented in the previous chapters provide strong support for this interpretation. The immediate encoding of emotional information can be deemed adaptive as it facilitates an affective and cognitive evaluation of the stimuli (Lazarus, 1982; 1984; Zajonc, 1980; 1984) and ensures the important information is available to guide both immediate and future decisions (Hamann, 2001). Hence, the immediate EEM is an adaptive function that relies on cognitive attributes of emotional stimuli.

In contrast however, the long-term storage of emotional stimuli is thought to rely on a process of consolidation, outlined in the modulation hypothesis (McGaugh, 2000; 2004). It is proposed that the arousal of emotional stimuli triggers a neurobiological response involving stress hormones, which activates receptors in the basolateral amygdala. This activation of the amygdala then in turn influences efferent projections to other brain regions such as the hippocampus, which facilitates the encoding of emotional information. This process of consolidation is thought to take a period of time, up to a few days, however it is also thought that this long-term emotional memory is more stable (Hamann, 2001; McGaugh, 2004; Talmi, Luk et al., 2007). Hence, it is adaptive to have a long-term stable memory for emotional information, to guide decisions and enhance survival for future occasions.

This work argues in favour of the two emotional memory process outlined above working together, as first proposed by Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007). If emotions and emotional memories are adaptive (Ekman, 1992a; LeDoux, 1995; Hamann, 2001; Phelps, 2006; Nairne et al., 2007), from an evolutionary perspective it stands to reason that if some emotional information is critical to immediate survival (e.g. to identify a potential predator), a mechanism to encode and store that information that takes a process of consolidation, over several days would not be suitable. Hence there must also be a mechanism whereby emotional information can be stored in memory immediately, so it can be used for immediate cognitive evaluations and fast decisions. This process relies on the cognitive attributes of emotional stimuli, as outlined above. However, this emotional information may be critical for survival, so needs to be well maintained in memory in a durable and stable form and as such, the long-term consolidation of the memory can then take over. This process takes several days, but in the meantime the organism has access to the immediate memory store, until the consolidation process is complete and there is a long-term store of the relevant emotional information, that will be more stable over time. This information can then be called upon in for cognitive evaluations of new information and to guide future decisions, to enhance survival.

6.9 Strengths and limitations of this work

6.9.1 Use of ERP and electrophysiological recordings

The use of electrophysiological recordings in all of the studies here is a particular strength to this body of research. Using a cognitive neuro-scientific technique allows a more precise examination of the cognitive mediating factors and furthers the behavioural research presented in the literature. Specifically the use of ERP measures in Chapters 2 and 3 has provided a more encompassing explanation of how the cognitive mediating factor of distinctiveness works. The two-step model was defined on the basis of the data obtained from the ERP recordings and has provided a functional account to the patterns of activity observed.

Similarly, the study in Chapter 5 found robust Dm effects primarily across anterior electrode sites for both mixed-negative and pure-negative items. These effects were consistent with evidence from the literature which suggests that Dm effects sensitive to semantic encoding and elaborative processing are primarily found across frontal electrode sites (Friedman & Johnson, 2000; Friedman & Trott, 2000). This shows the benefit of using ERP data, as it can strengthen a behavioural interpretation and accumulate evidence to enhance a hypothesis. Using ERP recordings in Chapter 5 also found no reliable Dm effects for the mixed-neutral or pure-neutral condition. This was interpreted as suggesting that previous Dm effects for neutral items may have been the result of participants trying to create inter-item links between the stimuli, to facilitate encoding (see 5.4 Discussion, Chapter 5). This was further interpreted as suggesting that part of the two-step model's processing, may involve creating inter-items links between the stimuli (see 5.4 Discussion, Chapter 5). This again demonstrates how using ERP data recordings provide additional evidence to support and refute hypothesis, which cannot be uncovered from the behavioural evidence alone. As mentioned using ERP recordings in Chapter 5 revealed the surprising result of robust Dm effect for pure-negative items compared to no reliable Dm effects observed for pure-neutral items. Coupled with the behavioural evidence showing a mnemonic memory advantage for pure-negative items, these findings were interpreted as showing that pure-negative items have privileged access to a processing route that neutral items cannot mobilise. This interpretation was greatly strengthened by the ERP evidence and again demonstrates the importance of including a neuro-scientific measure in these studies.

Further support for the strength of including ERP recordings come from the evidence presented in Chapter 4. The behavioural evidence presented in Chapter 4 found that arousal was unable to contribute to the immediate EEM. However, the ERP data did show a significant effect of arousal upon encoding related activity. This again highlights the significance of including neuro-scientific methods, as they can reveal findings that do not translate into the behavioural evidence; hence, the ERP findings of Chapter 4 revealed data that would otherwise be undetected. The evidence from Chapter 4 was interpreted as potentially reflecting the initial stages of the long-term consolidation of emotional memories and reflecting the role arousal plays in the modulation hypothesis. Therefore despite there being no significant effects of arousal in the behavioural data the ERP data of Chapter 4 supports interpretations as to the long-term consolidation of emotional memories from the literature and was hence an important inclusion in this study.

Although the ERP data was extremely useful for all the reasons highlighted above, the ERP data was unable to provide specific localised brain regions involved. Hence future studies should aim to incorporate localisation from functional magnetic resonance (fMRI) or position emission topography (PET) studies to both further these findings and support the interpretations of the evidence presented here. Several investigations in the literature have used fMRI studies to investigate the role that certain brain structures such as the amygdala play on the formation of emotional memories (Otten & Rugg, 2001; Dolcos, LaBar & Cabeza, 2004a; Dolcos, LaBar & Cabeza, 2004b; see LaBar & Cabeza, 2006 for review; see Kensinger, 2009 for review). However these studies have focused primarily on the long-term effects of EEM. Therefore future studies are needed to specifically localise the brain structures involved in the formation of immediate emotional memories.

6.9.2 Using mixed versus pure list design

Another strength of the studies used in this work, is the mixed versus pure list design paradigm. Using mixed-list designs allowed us to precisely examine the effects of distinctiveness and investigate the specific effects of relative distinctiveness and absolute distinctiveness (see 1.7.1 Distinctiveness, Chapter 1) in the immediate EEM. Likewise, using a pure-lists design allowed us to control for certain factors (relative distinctiveness and the associated attentional resources) and specifically examine other potential cognitive factors such as semantic relatedness and arousal. This is an important paradigm which has been previously used in the literature (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Sommer et al., 2008; Talmi & McGarry, 2012) and has proved a useful research design in this work.

Although using the mixed-versus pure-list design has been very important in this research, the study in Chapter 4 also highlighted an important thing to consider; specifically when implementing pure-list designs. When using pure-lists of images that contain intermixed levels of arousal (mixed high and low-arousal images), there is the possibility that the high-arousal items may preferentially capture the processing resources at the expense of low-arousal items. This can therefore reduce the availability of processing resources for low-arousal items and lead to a reduction in the amount of items successfully encoded. Hence, this is an important point to consider in the design of future experiments that may be investigating memory recall with a pure-list design; as the results may be being affected by the intermixed levels of arousal presented within the pure-list condition.

6.9.3 Use of unique number paradigm

A strength of the study conducted in Chapter 5 was the development of the unique number task. This task was specifically designed for the purposes of this study, to allow attention to be measured indirectly; that is to say, attention was not measured in a classic divided attention paradigm. The task itself was presented after every image an d involved participants making a quick ‘higher or lower’ decision based on the number presented on the screen. Both the reaction times and accuracy were recorded to the number task and used as an indirect measure of attention grabbing the previous image was. This task served the aims of the study well and provided an indirect measure of attention which was subsequently used to support the role of attention in the two-step model of distinctiveness. This newly developed task could therefore be implemented successfully in future studies that wish to have an indirect measure of attention. The results recorded from this number task provided evidence which revealed the possibility that pure-list conditions utilise primarily pre attentive resources, rather than overt selective attentional resources (Talmi, Schimmack et al., 2007; Pottage and Schaefer, 2012). Furthermore the attentional task was presented in the same visual modality as the encoding task (visually encode images). This has been shown to be an important factor (Schupp et al., 2008; Schupp et al., 2007; Schupp et al., 2006) as previous studies have shown when attentional tasks are presented in a different modality to the primary encoding task, they tap into different attentional resources; hence the attention task may not be affecting the same resources needed to encode the primary information.

Although this number paradigm was a very useful way to quickly gage a measure of the amount of overt attentional resources allocated to encoding the images, it does have limitations in the sense that the task only provided an indirect measure of attention. To specifically measure attention itself, a classic divided versus full attention paradigm would be better placed as demonstrated by previous studies in the literature (Pottage et al, 2012; Talmi, Schimmack et al., 2007). There is still a discrepancy in the literature as to the role of overt attentional resources in the immediate encoding of emotionally negative information; Talmi, Schimmack et al., (2007) found no significant mediating effects of attention involved in the encoding of negative information, whereas Pottage et al., (2012) found attention did significantly mediate the formation of immediate emotional memories. This study was unable to directly address these contrasting findings as the number task only provided an indirect measure of attention, rather than a specific attentional index. Hence, future studies need to employ a classic full versus divided attention paradigm to clarify the exact role that attention plays in the immediate EEM for both negatively valenced and positively valenced stimuli.

6.10 Future directions

Based on the findings of all four studies presented in this body of research, there are some key future directions that can be generally applied to all of the studies conducted in this work, to further the research into the formation of emotional memories.

As mentioned in Chapter 1 (see 1.7 Immediate EEM, Chapter 1) there is a large body of evidence presented in the behavioural literature which suggests there is a wide range of potential cognitive mediating factors, that could play a significant part in the immediate EEM. The studies presented in this work focused primarily on three key cognitive factors that Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) suggested are sufficient to fully account for the immediate EEM. The evidence presented in Chapter 5 suggested in contrary to the studies presented by Talmi and colleagues (Talmi, Luk et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012) that the cognitive mediating factor of semantic relatedness is unable to fully account for the immediate effects of EEM. This finding highlights the need to broaden the research focus when investigating the cognitive mediating factors responsible for the immediate EEM, beyond the key factors of distinctiveness, semantic relatedness and attention. Hence future studies should aim to investigate the impact that other potential cognitive mediating factors such as emotional regulation (Gross, 1998), which has been shown to have powerful effects upon emotional memory interactions (Richards & Gross, 2000; Gross, 2002). Another potential cognitive mediating factor that results of this work suggest could play a role in the immediate EEM and requires further research, is the self-referential processing that tends to accompany the processing of emotional stimuli (Conway & Pleydell-Pearce, 2000). The literature suggests that emotional items trigger deeper level of meaning-based processing (Schaefer et al., 2003). Specifically, self-based processing (self-referential) of emotional items has been found improve the details of memory and make the memory more vivid in comparison to neutral memories for neutral items (Schaefer & Philippot, 2005). These examples demonstrate that other cognitive factors can have specific effects upon the formation of emotional memories and future studies should investigate these factors more precisely, to examine the role they may play in the immediate EEM.

In addition to cognitive mediating factors, the work in Chapter 3 looked at the impact individual differences can have upon emotional memory. This area has not been investigated in depth within the literature so the work in Chapter 3 serves as an introduction as to how individual differences could affect emotional memory processes. The findings in Chapter 3 (see 3.4.2 Individual differences main findings, Chapter 3) overall found no significant main effects of the individual measures on emotional memory. The work generally had low statistical power, but never the less suggested the Big 5 personality measures and the BIS BAS scale did not meaningfully interact with ERP emotional memory indices. On the other hand the work presented on the OSPAN task did suggest working memory capacity can affect the working memory component suggested as part of the 2-step model of emotional memory (see 3.4.2 Individual differences main findings, Chapter 3). Hence this would be a avenue that of research into individual differences that future works could pursue. Similarly, the extensive literature of emotional regulation (Dillon et al., 2007; Richards & Gross, 2006; Gross, 2002; Richards & Gross, 2000; Richards & Gross, 1999) strongly suggests emotional regulation strategies can affect memory processes. Although the study in Chapter 3 did not find conclusive evidence to support this literature, future studies could explore the relationship between emotional regulation strategies and working memory performance, to see how they combine to impact EEM.

Another potential avenue of future research would be to incorporate neuro-scientific methods that allow a more precise localisation of the brain regions involved, when cognitive mediating factors exert their influence in the immediate EEM. The studies in this work have uncovered specific neural correlates of distinctiveness and semantic relatedness, which has developed functional accounts of how some of these factors work (e.g. distinctiveness and the two-step model). However, the exact brain regions involved when these cognitive mediating factors play a role in the immediate EEM, are still unknown. Studies in the literature have utilised position emission topography (PET) and functional magnetic resonance imaging (fMRI) techniques to uncover the specific brain regions and structures involved in the formation of emotional memories (Otten & Rugg, 2001; see McGaugh, 2004 for review; Dolcos, LaBar & Cabeza, 2004a; Dolcos, LaBar & Cabeza, 2004b; see LaBar & Cabeza, 2006 for review; see Kensinger, 2009 for review); however these studies have predominantly focused on the long-term consolidation of emotional memories, rather than the immediate effects of EEM. Hence, future studies should incorporate localisation methods such as PET or fMRI to uncover the specific brain structures and areas involved in the formation of immediate emotional memories.

One pertinent factor that needs to be considered in future research of emotional memories is how the valence of items can affect the relationships and findings highlighted in this work. The studies presented in this work only investigated the effects of emotional memory in regards to negatively valenced stimuli. However the literature does highlight some differences in how emotionally negative versus emotionally positive stimuli can effect memory formations (see Kensinger, 2009 for review). For example, some studies have shown that negatively valenced items can enhance memory for intrinsic details (see Kensinger, 2009 for review), whereas positively valenced stimuli can increase memory for the gist of an event (Fredrick et al., 2005). Furthermore, studies have shown that negative stimuli are associated with activity across temporal-occipital regions, whereas positive stimuli are associated with activity across frontal-parietal regions (Mickely & Kensinger, 2008). These studies suggest there may be key differences in how negative and positive stimuli are processed. Hence, future studies are needed to examine if the findings of the studies presented in this work can be generalised to positively valenced emotional stimuli or if the effects may be different.

The final factor that warrants further investigation in future studies is the sex-related differences that can occur in emotional processing (Tranel & Bechara, 2009; Cahill, Uncapher, Kilpatrick, Alkire & Turner, 2004; Cahill et al., 2001). Evidence from the literature has suggested that sex-related differences are commonly found in the amygdala (Kilpatrick, Zald, Pardo & Cahill., 2006). Studies have shown that enhanced activity in the left amygdala was associated with enhanced memory for emotional stimuli, for women; whereas enhanced activity in the right amygdala was associated with enhance emotional memory, for men (Cahill et al., 2001; Cahill et al., 2004). Moreover, evidence has now shown that activity in ERP studies is also susceptible to sex-related differences; when participants viewed emotionally arousing pictures the P3 amplitude was greater in the left hemisphere for women, whereas P3 amplitude was greater in the right hemisphere for men (Gasbarri et al., 2007). Furthermore, the literature also shows how sex-related differences in emotional processing have been found to influence neural activity during emotional regulation (Mak, Hu, Zhang, Xiao & Lee, 2009). Observing sex-specific brain regions involved in the regulation of emotional responses has been interpreted as potentially explaining why there are sex-related differences in disorders of emotion, such as females being more vulnerable to developing depression (Mak et al., 2009). These findings demonstrate that there are discrete sex-related differences during the processing of emotional stimuli, during the formation of emotional memories and during the cognitive regulation of emotional experiences. Hence, further studies are needed to examine more closely how sex-related differences effect the formation of emotional memories and importantly, future studies should be mindful of the impact that sex-related differences could have in their findings and conclusions.

6.11 Real world implications

Research into emotional memories has several important real world implications. The understanding of the underlying neurobiological routes and processes involved in forming emotional memories have been practically applied to understanding memory disturbances in affective disorders of emotion (LaBar & Cabeza, 2006) and have had a significant impact on legal systems across the world (Loftus, 2003). The studies presented in this work are therefore important as they have added to the understanding of emotional memories and provided new knowledge that can be incorporated or used to guide future therapies for disorders of emotion and practically inform legal practises.

Specifically research into emotion and memory has previously been applied to help form therapeutic techniques to treat disorders of emotional memory such as phobias and post-traumatic stress disorder (PTSD). PTSD is a psychiatric syndrome that develops in response to a traumatic event, such as warfare or a physical assault (Hayes, VanElzakker & Shin, 2012); it is often characterised by flashbacks and nightmares (Hayes et al., 2011). The neurobiological model of emotion and memory (see modulation hypothesis, McGaugh, 2000; 2004) has been used to formulate a neurobiological account of PTSD (Cahill, 1997). It has been proposed that PTSD occurs as a result of a positive feedback loop, which occurs within the mechanisms of the normally adaptive modulation process of emotional memories. The feedback loop proposes that re-experiencing a traumatic memory can produce stress hormones, which then stimulate the modulation process of emotional memories (see McGaugh, 2000; 2004). This response then strengthens that traumatic memory and therefore the likelihood of re-experiencing that traumatic event; hence creating a feedback loop to perpetuate the cycle. This process explains why individuals suffering with PTSD often re-experiencing the memory with flashbacks or nightmares. Research has shown that PTSD is characterised by a specific mechanism of emotional dysregulation, above that of an exaggerated fear response (Etkin & Wagner, 2007). Furthermore, it has been shown that PTSD can have further reaching effects beyond those of emotion and memory, affecting processes of cognitive control such as attention, planning and memory (Hayes et al., 2012).Understanding the fundamental processes that result in the adaptive modulation of emotional events is necessary to understand the mechanisms through which emotional dysregulation and PTSD occur and how PTSD can influence other important cognitive functions. Understanding these processes can in turn then enable a more efficient diagnosis of PTSD, help develop successful treatments and allow individuals to better manage the symptoms of PTSD. For example, the understanding of cognitive implications of PTSD has led to the suggestion that developing an affective working memory training system could facilitate the treatment of PTSD (Schweizer & Dalgleish, 2011). Other treatments have focused on the cognitive behavioural therapy

(CBT) technique to encourage a greater level of cognitive control over emotion, to enable individuals who suffer from PTSD to manage their symptoms (Hayes et al., 2012). The research into drug therapies has also developed, with the use of adrenergic receptor blockers used to compromise the memory enhancing effects of arousal during the onset of PTSD (Hayes et al., 2012).

Similarly, some of these treatments have also has been used to treat individual who suffer from specific phobias, such as fear of spiders. Specific phobias are one of the most common psychiatric disorders reported (Paquette et al., 2003) and are often characterised by an intense fear and avoidance behaviour, when presented with the specific phobic stimulus (Paquette et al., 2003). CBT has also successfully been applied to treating spider phobia (a type of specific phobia). Results from an fMRI study conducted by Paquette et al., (2003) have demonstrated that pre- CBT treatment, individuals with spider phobia have significant activation in the prefrontal cortex (a region thought to reflect the emotional regulation processes triggered as a result of the fear response) and the hippocampus (a region thought to reflect the individual reactivating a contextual fear memory). However after CBT treatment, these areas were no longer significantly activated, suggesting the CBT has the potential to treat the dysfunctional processes associated with anxiety disorders. These examples therefore emphasises the importance that research into emotional memories has had in the development of treatments for disorders of emotion and memory.

In addition to the therapeutic impact that research into emotional memories has had, the scientific understanding of emotional events has had a significant impact on the legal systems across the world (Loftus, 2003). It is well documented in the literature that even minor memory distortions can have severe consequences to legal proceedings (Lacey & Stark, 2013) and as such understanding emotional memory systems has helped combat issues in the criminal justice system; this research has guided practice in the use of eyewitness testimony (Loftus, 2003) and helped form specific cognitive interview techniques (Memon & Meissner, 2010). Research into eyewitness testimonies is well documented in the literature (see 1.4.3, Chapter 1 for more details), with many investigations showing eyewitness testimonies are not fixed (Loftus, 2003) and can lack detail (Kensinger, 2004). Furthermore, research has shown that these memories are susceptible to change, even by information provided after the event (Loftus & Palmer, 1974). Despite the fragility of eyewitness testimonies, historically they have been central to many court cases and as such, have been responsible for numerous wrongful convictions (Lacy & Stark, 2013; Loftus, 2003). Research into emotional memories has revealed ways to maximise the amount of accurate details retrieved from memory. This research has specifically lead to the development of techniques that police forces can use to enhance the reliability of eyewitness testimonies such as the cognitive interview. The cognitive interview is a well-established protocol used for interviewing witnesses (Memon & Meissner, 2010). This technique was based on research into remembering details and successfully retrieving accurate information from memory and developed to improve witness statements. A meta-analysis on cognitive interviews has shown that the communication techniques used significantly improve the number of correct details remembered, while only showing small increases in the memory for incorrect details (Memon et al., 2010). This shows how vital the research into emotions and memory can be and the practical implications that have developed as a result of such work.

6.12 Concluding remarks

This work focused on the key cognitive mediating factors (as outlined by the behavioural literature, Talmi & McGarry, 2012) involved in the immediate EEM and explored the role that these factors play using ERP measures, to further the interpretations of the behavioural literature. This work found that distinctiveness plays a significant role in the immediate EEM and outlined a functional two-step account of the processes involved, when distinctiveness is allowed to pay a role in the immediate EEM. This work also found that although semantic relatedness can improve overall recall rates; alone, the factor of relatedness is unable to fully account for the immediate EEM, as Talmi and colleagues proposed (Talmi, Luk, et al., 2007; Talmi, Schimmack et al., 2007; Talmi & McGarry, 2012). This work found that attention plays a crucial role in the mixed-list conditions; alongside the factor of distinctiveness, it is evident that overt selective attentional resources are involving in the processing of negative items to facilitate successful encoding. In contrast however, this evidence suggest that negative items in pure-list conditions may rely on pre-attentive resources to contribute to the mnemonic memory advantage of negative items over neutral items. This work also uniquely investigated the role that arousal can have on the immediate EEM. The behavioural findings suggested that arousal alone (in the absence of other cognitive mediating factors) was unable to enhance the immediate EEM. The ERP findings however, did find a significant effect of arousal upon encoding related activity, which was interpreted as providing support for the modulation hypothesis and the long-term consolidation of emotional memories. Overall, this work therefore supports the hypothesis of Talmi (2013), which suggested that the cognitive mediating model account for the immediate EEM, whereas the modulation theory account for the long-term consolidation of emotional memories. Hence, both models together provide a complimentary encompassing account of how the emotional enhancement of memory works. This work however does highlight the need for future studies to broaden the focus and research into cognitive mediating factors, beyond the key three factors mentioned in the literature (Talmi & McGarry, 2012). Future studies should also aim to include neuro-scientific methods into their investigations, to enhance the understanding of the cognitive mediating factors and provide functional accounts of how these factors exert their influence in the immediate EEM. As mentioned the research into emotional memories in general is very pertinent as it has important implications to the development of treatments for emotional disorders and can be used to practically inform and improve legal practises across the world.

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Appendix A: The Beck's Depression Inventory

This next questionnaire consists of 21 groups of statements.
After reading carefully each group of statements, mark the box of the one statement in each group which best describes the way you have been feeling *during the past two weeks*, including today.
If several statements in the group seem to apply equally well, check the strongest statement which applies.
Be sure that you do not choose more than one statement for any group, including item 16 (changes in sleep pattern) or item 18 (changes in appetite).
Be sure to read all the statements in each group before making your choice.

	1
I do not feel sad	
I feel sad much of the time	
I am sad all the time	
I am so sad or unhappy that I can't stand it	

	2
I am not discouraged by my future	
I feel more discouraged about my future than I used to be	
I do not expect things to work out for me	
I feel my future is hopeless and will only get worse	

	3
I do not feel like a failure	
I have failed more than I should have	
As I look back, I see a lot of failures	
I feel I am a total failure as a person	

	4
I get as much pleasure as I ever did from the things I enjoy	
I don't enjoy things as much as I used to	
I get very little pleasure from the things I used to enjoy	
I cant get pleasure from the things I used to enjoy	

	5
I don't feel particularly guilty	
I feel guilty over many things i have done or should have done	
I feel quite guilty most of the time	
I feel guilty all of the time	

	6
I don't feel I am being punished	
I feel I may be punished	
I expect to be punished	
I feel I am being punished	

	7
I feel the same bout myself as ever	
I have lost confidence in myself	
I am disappointed in myself	
I dislike myself	

	8
I don't criticise or blame myself more than usual	
I am more critical of myself than I used to be	
I criticise myself for all my faults	
I blame myself for everything bad that happens	

9

I don't have any thoughts of killing myself	
I have thoughts of killing myself, but I would not carry them out	
I would like to kill myself	
I would kill myself if I had the chance	

10

I don't cry anymore than I used to	
I cry more than I used to	
I cry over every little thing	
I feel like crying but I can't	

11

I am no more restless or wound up than usual	
I feel more restless and wound up than usual	
I am so restless or agitated that its hard to stay still	
I am so agitated or restless that I have to keep moving or doing something	

12

I have not lost interest in other people or activities	
I am less interested in other people or things than before	
I have lost most of my interest in other people or things	
It's hard to get interested in anything	

13

I make decisions about as well as ever	
I find it more difficult to make decisions than usual	
I have much greater difficulty in making decisions than I used to	
I have trouble making any decisions	

14

I do not feel I am worthless	
I don't consider myself as worthwile and useful as I used to do	
I feel more worthless compared to other people	
I feel utterly worthless	

15

I have as much energy as ever	
I have less energy than I used to have	
I don't have enough energy to do very much	
I don't have enough energy to do anything	

16

I have not experienced any change in my sleeping pattern	
I sleep somewhat more than usual	
I sleep somewhat less than usual	
I sleep a lot more than usual	
I sleep a lot less than usual	
I sleep most of the day	

17

I am no more irritable than usual	
I am more irritable than usual	
I am much more irritable than usual	
I am irritable all of the time	

18

I have not experienced any change in my appetite	
My appetite is somewhat less than usual	
My appetite is somewhat greater than usual	
My appetite is much less than before	
My appetite is much greater than normal	
I have no appetite at all anymore	

19

I can concentrate as well as ever	
I cant concentrate as well as usual	
I It's hard to keep my mind on anything for very long	
I find I cant concentrate on anything	

20

I am no more tired or fatigued than usual	
I get more tired or fatigued more easily than usual	
I am too tired or fatigued to do a lot of things I used to do	
I am too tired or fatigued to do most of the things I used to do	

21

I have not noticed any recent change in my interest in sex	
I am less interested in sex than I used to be	
I am much less interested in sex now	
I have lost interest in sex completely	

Appendix B: The State-Trait Anxiety Inventory

Please read Carefully through the Statements and give the appropriate response using the scale below

1 = I **NEVER** feel like this
2 = I **OCCASIONALLY** feel like this
3 = I **SOMETIMES** feel like this
4 = I **OFTEN** feel like this
5 = I feel like this **ALL** the time

Please indicate how you feel about each statement.

1. I feel pleasant.
2. I feel nervous and restless.
3. I feel satisfied with myself.
4. I wish I could be as happy as others seem to be.
5. I feel like a failure.
6. I feel rested.
7. I am "calm, cool, and collected".
8. I feel that difficulties are piling up so that I cannot overcome them.
9. I worry too much over something that really doesn't matter.
10. I am happy.
11. I have disturbing thoughts.
12. I lack self-confidence.
13. I feel secure.
14. I make decisions easily.
15. I feel inadequate.
16. I am content.
17. Some unimportant thought runs through my mind and bothers me.
18. I take disappointments so keenly that i can't put them out of my mind.
19. I am a steady person.
20. I get in a state of tension or turmoil as I think over my recent concerns and interests.

Appendix C: Raw data scores, Descriptive data and ERP correlational data for the OSPAN task

Table showing raw OSPAN data scores for each participant:

Subjects	OSPAN Absolute Score
101	35
102	32
103	56
105	35
106	28
107	68
108	48
109	68
111	49
112	55
113	48
114	11
115	69
116	23
117	31
118	13
119	28
120	17
121	34
122	32
123	50
124	37
127	43
129	3
130	62
131	43
134	45
135	42
136	68
138	28
139	3
140	36
142	34
143	29

Table showing descriptive data of OSPAN scores:

Mean OSPAN score	38.32
Range OSPAN score	69-3
Median split	35.5

ERP correlation data for OSPAN scores:

Table to show Pearson's correlations for regional scalp clusters

	OSPAN Score		
Regional Scalp Clusters (Dm activity)	**200-400ms time window**	**400-800ms time window**	**800-1500ms time window**
Anterior Mixed Negative	.032	.107	-.028
Anterior Mixed Neutral	.177	.160	.114
Anterior Pure Negative	.094	-.087	-.082
Anterior Pure Neutral	.108	.009	-.151
Posterior Mixed Negative	-.011	.012	-.104
Posterior Mixed Neutral	.407*	.264	.231
Posterior Pure Negative	.195	.036	.165
Posterior Pure Neutral	.141	.227	.031

*. Correlation is significant at the 0.05 level

Table to show Pearson's correlation for whole scalp clusters

	OSPAN Score		
Whole Scalp Clusters (Dm activity)	**200-400ms time window**	**400-800ms time window**	**800-1500ms time window**
Mixed Negative	.013	.050	-.085
Mixed Neutral	.348*	.168	.100
Pure Negative	.185	.101	.089
Pure Neutral	.125	.693**	-.074

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Appendix D: Emotional Regulation Questionnaire Raw data scores and correlational statistics

Table to show the raw data scores for each participant for both reappraisal and suppression

Subjects	Cognitive Reappraisal	Expressive Suppression
101	18	18
102	34	15
103	24	19
105	21	13
106	27	22
107	33	11
108	31	12
109	27	19
111	32	13
112	29	14
113	27	14
114	21	14
115	37	19
116	24	15
117	30	5
118	33	16
119	26	7
120	36	12
121	34	10
122	35	12
123	36	6
124	26	19
127	33	19
129	24	5
130	33	20
131	29	15
134	29	16
135	40	8
136	30	17
138	29	24
139	35	4
140	22	11
142	34	13
143	33	8

Table to show the descriptive data for the reappraisal and suppressions scores

	Mean	Standard deviation
Reappraisal scores	29.76	5.25
Suppression scores	13.68	5.09

Table to show the resulting scores of the median split for the reappraisal and suppression scores

	Mean score	Standard deviation
High reappraisers	34.06	2.36
Low reappraisers	25.47	3.47
High suppressors	17.71	3.82
Low suppressors	9.65	3.30

ERP correlation data for OSPAN scores:

Table to show the Kendall's tau-b correlations for regional scalp clusters and the reappraisal and suppression scores

Regional Scalp Clusters (Dm activity)	Reappraisal Score		
	200-400ms time window	**400-800ms time window**	**800-1500ms time window**
Anterior Mixed Negative	-.086	-.115	-.222
Anterior Mixed Neutral	.038	.068	-.104
Anterior Pure Negative	.148	.141	.115
Anterior Pure Neutral	.145	-.013	-.060
Posterior Mixed Negative	.108	-.082	-.119
Posterior Mixed Neutral	.086	-.064	-.024
Posterior Pure Negative	.097	.112	.046
Posterior Pure Neutral	.071	-.057	-.097

Regional Scalp Clusters (Dm activity)	Suppression Score		
	200-400ms time window	**400-800ms time window**	**800-1500ms time window**
Anterior Mixed Negative	.111	-.075	.002
Anterior Mixed Neutral	.111	-.005	.130
Anterior Pure Negative	-.046	-.013	-.093
Anterior Pure Neutral	-.235	-.203	-.100
Posterior Mixed Negative	-.068	-.155	-.199
Posterior Mixed Neutral	-.035	-.027	.057
Posterior Pure Negative	-.013	-.126	-.089
Posterior Pure Neutral	-075	.013	.210

Table to show the Kendall's tau-b correlations for the whole scalp clusters, for the reappraisal and suppression scores

Whole Scalp Clusters (Dm activity)	**Reappraisal Score**		
	200-400ms time window	**400-800ms time window**	**800-1500ms time window**
Mixed Negative	-.068	-.119	-.196
Mixed Neutral	.053	-.005	-.112
Pure Negative	.141	.159	.126
Pure Neutral	.097	-.068	-.093

Whole Scalp Clusters (Dm activity)	**Suppression Score**		
	200-400ms time window	**400-800ms time window**	**800-1500ms time window**
Mixed Negative	.060	-.144	-.078
Mixed Neutral	.068	-.024	.075
Pure Negative	-.042	-.133	-.097
Pure Neutral	-.188	-.108	.027

Appendix E: The Big 5 Inventory raw data score, descriptive data and correlational statistics data

A table to show the Big 5 raw data scores for each participant

Subjects	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
101	18	38	39	16	33
102	28	38	37	15	38
103	20	31	28	18	34
105	18	33	31	30	26
106	25	41	32	29	41
107	25	42	21	24	31
108	14	12	17	22	26
109	17	23	18	14	21
111	26	15	22	22	27
112	13	18	22	22	23
113	20	19	22	25	22
114	16	20	24	19	14
115	19	12	20	18	27
116	23	18	20	19	19
117	22	21	19	24	23
118	20	18	24	20	21
119	23	16	26	21	26
120	26	19	25	20	28
121	17	15	20	21	26
122	26	14	19	20	23
123	21	18	18	24	22
124	14	21	17	15	24
127	19	20	20	21	23
129	26	19	20	24	23
130	19	19	29	16	23
131	14	11	29	25	26
134	16	15	24	20	22
135	21	20	18	21	25
136	22	20	21	24	24
138	21	16	20	19	26
139	18	12	15	21	24
140	23	20	18	19	23
142	16	19	18	17	26
143	22	21	21	18	25

A table to show the descriptive data for each factor of the Big 5 Inventory

	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Mean	20.24	21.00	22.76	20.68	25.44
Standard Deviation	4.03	8.31	5.69	3.72	5.14

Tables to show the Kendall's tau-b correlations for regional scalp clusters and the Big 5 Inventory facets, for each of the three time windows

Regional Scalp Clusters (Dm activity)	**200-400ms**				
	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Anterior Mixed Negative	-.295*	-.036	-.187	-.048	-.039
Anterior Mixed Neutral	.057	-.098	-.182	-.158	.064
Anterior Pure Negative	.010	.065	-.077	-.120	0.00
Anterior Pure Neutral	.029	.070	-.058	.134	.137
Posterior Mixed Negative	-.343**	-.204	.096	-.067	-.049
Posterior Mixed Neutral	.033	-.036	.129	.014	-.113
Posterior Pure Negative	.076	-.031	.014	.120	.210
Posterior Pure Neutral	.038	.060	-.010	.115	.093

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Regional Scalp Clusters (Dm activity)	400-800ms				
	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Anterior Mixed Negative	-.171	.050	-.067	.096	.039
Anterior Mixed Neutral	-.100	-.238	.034	.029	.059
Anterior Pure Negative	-.157	.084	-.134	-.091	.010
Anterior Pure Neutral	-.109	.070	-.072	.101	-.069
Posterior Mixed Negative	-.152	-.161	-.062	.067	-.069
Posterior Mixed Neutral	-.014	-.022	.058	-.014	-.176
Posterior Pure Negative	.090	-.070	.010	.144	-.254
Posterior Pure Neutral	-.176	-.012	.082	.096	-.078

Regional Scalp Clusters (Dm activity)	800-1500ms				
	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Anterior Mixed Negative	-.233	.118	-.105	-.019	-.010
Anterior Mixed Neutral	-.171	-.132	.024	-.115	.117
Anterior Pure Negative	-.214	.122	-.153	.067	.049
Anterior Pure Neutral	-.076	.113	-.043	.077	-.181
Posterior Mixed Negative	-.143	-.122	-.058	.058	-.161
Posterior Mixed Neutral	-.029	-.012	.067	-.072	-.098
Posterior Pure Negative	.157	.074	.053	.091	-.259
Posterior Pure Neutral	-.362**	.031	.120	.038	-.254

Tables to show the Kendall's tau-b correlations for whole scalp clusters and the Big 5 Inventory facets, for each of the three time windows

Whole Scalp Clusters (Dm activity)	200-400ms				
	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Mixed Negative	-.371**	-.108	-.077	-.058	-.049
Mixed Neutral	-.019	-.089	-.034	-..048	.010
Pure Negative	.010	-.026	-.053	.067	-.166
Pure Neutral	-.010	.070	-.019	.153	.098

**. Correlation is significant at the 0.01 level

Whole Scalp Clusters (Dm activity)	**400-800ms**				
	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Mixed Negative	-.152	-.007	-.067	.096	.024
Mixed Neutral	-.090	.-.142	.072	-.038	-.083
Pure Negative	.000	-.036	-.029	-.029	-.166
Pure Neutral	-.124	.031	.043	.082	-.064

Whole Scalp Clusters (Dm activity)	**800-1500ms**				
	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Mixed Negative	-.224	.031	-.082	-.010	-.093
Mixed Neutral	-.057	-.084	.101	-.077	-.010
Pure Negative	-.010	.079	-.058	.000	-.176
Pure Neutral	-.171	.089	.062	.067	-.220

Appendix F: The BIS/BAS scales raw scores, descriptive data and correlational statistics

Table to show the raw BIS/BAS scores for each participant

Subjects	BAS Drive	BAS Fun Seeking	BAS Reward Responsiveness	BIS
101	13	15	23	21
102	17	16	24	25
103	15	16	18	25
105	12	14	24	28
106	12	18	20	25
107	11	14	22	27
108	16	14	21	25
109	11	12	21	28
111	15	17	25	23
112	12	17	22	22
113	13	14	24	31
114	15	18	17	26
115	12	14	22	23
116	16	15	22	25
117	12	18	23	27
118	14	14	21	25
119	16	17	25	25
120	16	14	25	30
121	14	18	23	29
122	16	13	22	23
123	16	20	24	21
124	13	18	21	29
127	15	17	25	26
129	13	17	22	28
130	13	12	18	22
131	18	20	24	18
134	11	18	23	25
135	18	14	21	26
136	20	18	20	26
138	12	16	21	31
139	18	18	24	28
140	15	16	25	25
142	17	19	21	28
143	15	14	22	32

Table to show the descriptive data for the BIS/BAS scales

	BAS Drive	BAS Fun Seeking	BAS Reward Responsiveness	BIS
Mean	14.47	16.03	22.21	25.82
Standard Deviation	2.34	2.18	2.09	3.13

Tables to show the Kendall's tau-b correlations for regional scalp clusters and the BIS/BAS scales Inventory facets, for each of the three time windows

Regional Scalp Clusters (Dm activity)	**200-400ms**				
	BIS	BAS	BAS Drive	BAS Fun seeking	BAS Reward
Anterior Mixed Negative	-.017	-.009	-.136	.232	-.011
Anterior Mixed Neutral	-.017	-.035	-.095	-.004	-.130
Anterior Pure Negative	.036	-.135	.053	-.162	-.115
Anterior Pure Neutral	-.009	-.017	-.117	-.077	.161
Posterior Mixed Negative	.021	-.079	-.049	.112	-.084
Posterior Mixed Neutral	-.164	.020	-.042	-.093	.077
Posterior Pure Negative	-.047	-.193	-.132	-.127	-.096
Posterior Pure Neutral	.089	-.013	-.163	.050	.061

Regional Scalp Clusters (Dm activity)	**400-800ms**				
	BIS	BAS	BAS Drive	BAS Fun seeking	BAS Reward
Anterior Mixed Negative	.017	.061	-.068	.143	.065
Anterior Mixed Neutral	-138	.039	-.091	.131	-.008
Anterior Pure Negative	.092	-.046	.042	.015	-.103
Anterior Pure Neutral	-.036	-.020	-.238	.000	.184
Posterior Mixed Negative	-.089	.050	-.064	.127	.184
Posterior Mixed Neutral	-.115	.068	-.148	.058	.126
Posterior Pure Negative	-.032	-.002	-.057	-.066	.157
Posterior Pure Neutral	.070	.064	-.242	.154	.211

Regional Scalp Clusters (Dm activity)	800-1500ms				
	BIS	BAS	BAS Drive	BAS Fun seeking	BAS Reward
Anterior Mixed Negative	.138	-.042	-.163	.124	-.057
Anterior Mixed Neutral	-.111	-.116	-.257*	.008	-.023
Anterior Pure Negative	.160	.053	.091	.062	-.046
Anterior Pure Neutral	-.032	-.042	-.235	.035	.100
Posterior Mixed Negative	.066	-.013	-.053	.131	.000
Posterior Mixed Neutral	-.123	.009	-.144	.100	.023
Posterior Pure Negative	.021	-.061	-.102	-.108	.084
Posterior Pure Neutral	.047	-.182	-.390**	.081	-.065

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Tables to show the Kendall's tau-b correlations for whole scalp clusters and the BIS/BAS scales, for each of the three time windows

Whole Scalp Clusters (Dm activity)	200-400ms				
	BIS	BAS	BAS Drive	BAS Fun seeking	BAS Reward
Mixed Negative	.006	-.020	-.102	.251*	-.023
Mixed Neutral	-.179	.013	.568	.039	-.019
Pure Negative	-.006	-.182	-.068	-.139	-.107
Pure Neutral	.047	-.050	-.166	-.042	.123

*. Correlation is significant at the 0.05 level

Whole Scalp Clusters (Dm activity)	**400-800ms**				
	BIS	BAS	BAS Drive	BAS Fun seeking	BAS Reward
Mixed Negative	-.006	.076	-.083	.151	.161
Mixed Neutral	-.175	.024	-.155	.081	.077
Pure Negative	.055	-.028	-.076	-.019	.054
Pure Neutral	.017	.024	-.299*	.089	.253*

*. Correlation is significant at the 0.05 level

Whole Scalp Clusters (Dm activity)	**800-1500ms**				
	BIS	BAS	BAS Drive	BAS Fun seeking	BAS Reward
Mixed Negative	.115	-.064	-.155	.097	-.061
Mixed Neutral	-.145	.006	-.227	.120	.073
Pure Negative	.055	-.013	-.038	-.042	.027
Pure Neutral	-.002	-.127	-.337**	.093	.046

**. Correlation is significant at the 0.01 level

<u>Appendix G: Sample of images used in experimental chapters 2, 3 and 4</u> (average valence and arousal ratings of each image included in parenthesis: whereby valence 1 = negative, 5 = positive and arousal 1 = calm, 5 = excited/anxious)

Please note: some of the following images some people may find disturbing (pg 275-279)

- **IAPS images**

Neutral images (valence/arousal ratings)


(3.06/1.94)


(3.33/1.67)


(3.44/2.11)


(3.00/2.22)


(2.89/2.72)

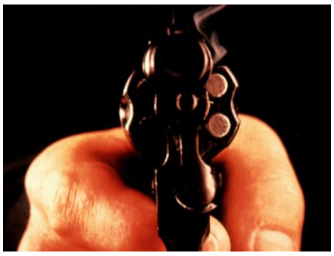
Low-arousal images (valence/arousal ratings)


(1.83/2.78)


(2.44/2.94)


(2.64/2.68)


(2.44/3.11)


(2.23/3.00)

High-arousal images (valence/arousal ratings)


(1.89/3.67)


(1.17/4.11)


(1.47/3.95)


(2.39/3.33)


(1.67/3.22)

- **Google images added to IAPS image set to balance images for the presence of humans animals and objects.**

Neutral images from Google (valence/arousal ratings)

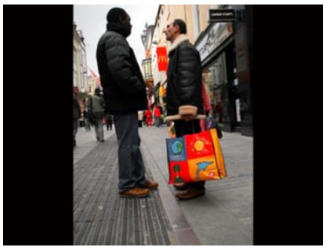

(2.75/1.63)


(2.75/2.25)


(3.75/1.63)


(2.88/1.75)


(3.88/1.75)


(3.13/1.50)


(2.88/1.50)


(3.17/1.33)

Low-arousal images added from Google (valence/arousal ratings)


(2.11/2.83)


(2.22/3.00)


(2.06/3.06)


(2.10/3.05)


(2.23/2.82)


(2.11/2.94)


(2.05/2.91)


(2.64/2.32)

High-arousal images added from Google (valence/arousal ratings)


(1.77/3.27)


(1.67/3.44)


(2.06/3.33)


(1.55/3.36)


(1.61/3.78)


(1.94/3.28)


(1.36/3.91)


(1.72/3.44)

Appendix H: Sample of images controlled for relatedness, used in experimental chapter 5

Neutral images

Negative images